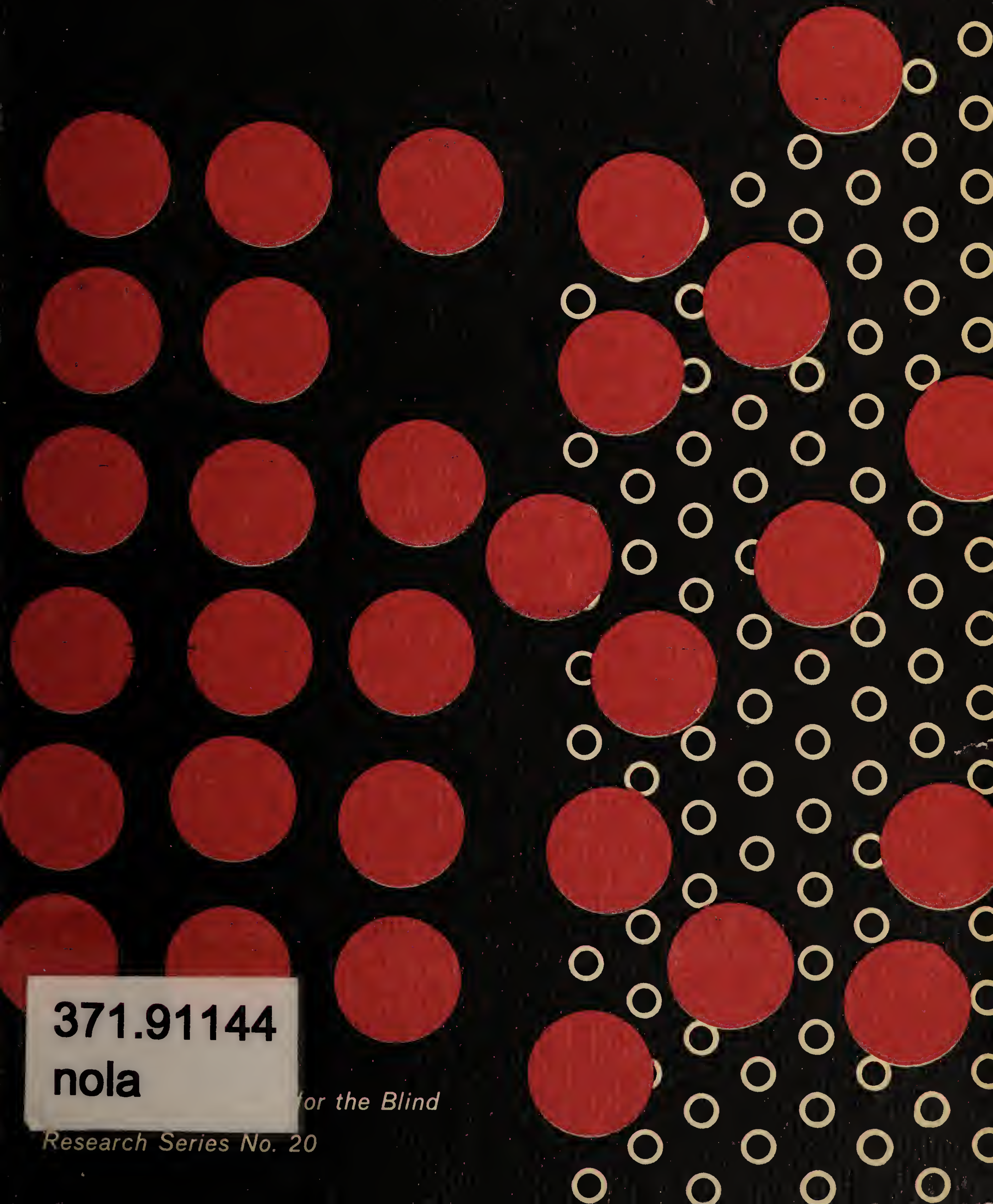
Perceptual Factors in Braille Word Recognition

Carson Y. Nolan
Cleves J. Kederis



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Perceptual Factors in Braille Word Recognition

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Foreword

This monograph presents the findings of several years of study of the braille system as a communication process. The studies were conducted by the Department of Educational Research of the American Printing House for the Blind. The primary finding of the study is that the braille code is perceived one character, or cell, at a time—a subject which is often debated.

We publish this monograph with considerable pride and would like to take the occasion to compliment the Director and staff of the Department of Educational Research of the American Printing House for the Blind for the continued excellence of their work, and to wish them equal success in the future.

M. Robert Barnett
Executive Director
American Foundation for the Blind

Acknowledgments

Many individuals have contributed to the work described in this monograph. Particular thanks are due to the administrative staffs of the Indiana School for the Blind, the Kansas School for the Blind, the Kentucky School for the Blind, the Michigan School for the Blind, the Missouri School for the Blind, the Ohio State School for the Blind, and the Tennessee School for the Blind for supplying facilities for the research and to their students for participation as subjects.

Mr. Max Wastl and the staff of the Lafayette Instrument Company were primarily responsible for bringing the tachistotactometer from the written specifications to concrete form. Mr. Virgil E. Zickel of the American Printing House assisted in development of this device and was responsible for the methods for producing the braille materials used.

Mrs. Sara W. Smith assisted in collecting the data for Study II, and Mr. Stanley Craig assisted in collecting the data for studies III and IV.

Dr. John R. Binford of the University of Louisville served as consultant throughout the study. Study I is drawn largely from a Master's Thesis (Kederis, 1962) written under his direction. He also reviewed much of the manuscript.

Dr. Samuel C. Ashcroft of George Peabody College acted as consultant and reviewed much of the manuscript. Peabody graduate students in special education who made comments on parts of the manu-

script included Miss Freda Henderson, Miss Evelyn Rex, and Mr. Larry Geffen.

The research reported as Study IX was conducted by Miss Freda Henderson, then a research intern at the American Printing House. It served as the basis for an Educational Specialist Thesis at George Peabody College (Henderson, 1967) written under the direction of Dr. Samuel C. Ashcroft. Miss Lulu Wash participated in training the students who served as subjects in this study.

Miss June Morris of the American Printing House reviewed the manuscript for format and grammatical construction. Mrs. Carole Wynn typed the manuscript.

All reviewers have contributed much to the quality of the manuscript and in no way are responsible for its failings.

Finally, the authors wish to express their appreciation to Mr. Finis E. Davis of the American Printing House for providing the opportunity for this research.

CYN

CJK

Contents

Foreword *iii*
Acknowledgements *v*
Preface *xi*

PART ONE *1*

ONE
A Brief Description of Braille *3*
TWO
Review of Research on Braille *7*
THREE
Summaries of the Nine Research Studies *23*
FOUR
Conclusions *35*
FIVE
Duplications of the Research *49*

PART TWO *55*

SIX
Study I: Legibility of Single-Cell Braille Characters *57*

SEVEN

Study II: The Effects of Word Length, Familiarity, and Orthography on Recognition Thresholds for Braille Words *71*

EIGHT

Study III: Influence of Numbers of Dots and Position of Dots on Recognition Thresholds for Braille Words *87*

NINE

Study IV: Influence of Braille Contractions upon Recognition Thresholds for Words *95*

TEN

Study V: Effects of Context upon Recognition Thresholds for Braille Words That Vary in Length, Familiarity, and Orthography *101*

ELEVEN

Study VI: Effects of Context Occurring in Continuous Text on Recognition Times for Stimulus Words of Study Two *109*

TWELVE

Study VII: Effects of Familiarity, Length, and Orthography of Braille Words on Their Recognition Thresholds at the Elementary School Level *117*

THIRTEEN

Study VIII: Braille Word Recognition by Readers of Low Intelligence *131*

FOURTEEN

Study IX: Effect of Character Recognition Training on Braille Reading *145*

APPENDIX A

Words Utilized as Stimuli in Studies II, V, VI, VII, and VIII *153*

APPENDIX B

Stimulus Words Used in Study II *155*

APPENDIX C

Stimulus Words Used in Study IV *157*

APPENDIX D

Study V: Context and Stimulus Words *159*

APPENDIX E

Study VI: Short Story Read by Subjects With Stimulus Words in Italics *165*

Bibliography on Braille Research *169*

Additional References *176*

Preface

The research described in this monograph represents an attempt to understand how braille is read. Extensive study of visual reading has led to the conclusion that words and even phrases are perceived simultaneously as wholes or units. This work is summarized in Vernon (1931), Woodworth (1938), and Anderson and Dearborn (1952). Photographic study of eye movement during reading has shown that the eyes move in jumps interspersed with short fixations and that perception occurs during the fixation periods. Tachistoscopic studies of print material have shown that groups of letters, words, and groups of words are recognized in the same amount of time as the individual letters of the alphabet. Other rapid exposure studies of word recognition have identified certain stimulus characteristics which affect word perception.

Anderson and Dearborn called these characteristics *cues* and classified them into three main groups—*(1)* individual letters, *(2)* small letter groups, and *(3)* word shape. Category 1 includes the physical characteristics of the letters—ascending limbs, descending limbs, and capitals; position of letters within words—initial and final; and letter function—vowels. Category 2 includes double letters, prefixes, and suffixes. Category 3 was generated by research findings that the total word structure, as determined not only by the outline of the word, but by the internal pattern of letters as well, facilitates the perception of the word. Subjective factors found to be tied in with all of the above are familiarity of the word, reading ability, and age or grade. Consequently, it became generally agreed that familiar words are perceived as wholes by means of their total structure under the influence of certain characteristics of the components and that the influence of these factors varies with the age, grade, and reading ability of the reader.

In the case of braille reading, it has not been explicitly demonstrated that such phenomena occur, but it does seem to be implicitly assumed that tactual reading proceeds in a manner similar to that for print. For example, Horbach (his research is mentioned in Chapter 2) stated: "Differences (between print and braille reading) can only be of gradual nature" (1951, p. 49). Ashcroft, in a study of braille reading errors, took as his basic underlying premise ". . . reading, no matter what the medium, fundamentally involves the same psychological processes . . . " (1960, p. 49). These statements are believed to sum up the present-day conception of the braille reading process. They indicate or imply that the perceptual unit in braille reading is the whole word, with word shape operating as a principal cue in word recognition.

It was within this conceptual framework that the research described in this monograph originated. Its purpose was to study factors in braille word recognition in order to delineate more clearly the cues that make braille reading by the whole word method possible. Knowledge of the factors important to perception in braille reading would have wide application in the evaluation of current instructional methods, refinement of remedial reading training techniques and, possibly, in development of training programs for increasing braille reading speeds.

The Plan for This Monograph

The student who aspires to appear scientific is compelled by the rules of science to write a detailed and often highly technical description of his work. This requirement results in the type of publication that dismays many teachers because they lack the technical information required for comprehension or the time to wade through the details reported. In order to circumvent these problems, at least partially, this monograph has been divided into two major sections.

Part One consists of five chapters. The first, a short chapter, describes braille and the terminology of the experiments. Chapter Two provides a general review of research on braille; research topics particularly relevant to perceptual problems in braille reading are emphasized. The next chapter presents, in brief outline form, each of the nine experiments included in the project. The results of these studies are integrated in the succeeding chapter to arrive at an over-all concept of the braille reading process. The final chapter in Part One explores the implications of this concept for teaching braille reading and for further research in this area.

Part Two consists of technical reports of the nine experiments.

PART ONE

ONE

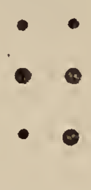
A Brief Description of Braille

BRAILLE is a system of printing and writing which consists of tactually distinguishable, raised dot patterns which represent the elements of a language or other graphic symbology. The several different grades of braille and special braille codes for music and mathematics are based on the same basic dot patterns. The grades of braille refer to the degree of complexity or number of contractions within the system. Two grades of braille are officially approved for use in this country by the AAIB-AAWB Braille Authority. English braille grade 1 uses full spelling and consists of the letters of the alphabet, numbers, and punctuation and composition signs. English braille grade 2 is a highly contracted system and consists of grade 1 and 189 contractions and abbreviated words. It is the latter with which this paper is concerned.

The braille characters are composed of the 63 possible combinations of one to six dots within an array of six equally spaced positions, three high by two wide, called the braille cell. For convenience in describing the characters, the positions that dots can occupy within the cell are numbered on the left downward 1, 2, 3 and on the right downward 4, 5, 6:

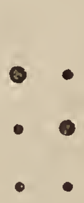
1 • • 4
2 • • 5
3 • • 6

In braille grade 2 there are 263 elements, or meanings, assigned to the 63 characters. The elements consist of the letters of the alphabet, letter sequences, words, numbers, punctuation, and pronunciation and composition signs. Practically all of the 63 characters are assigned more than one meaning. The meaning of a character varies according to its relationship to adjacent characters. For example:

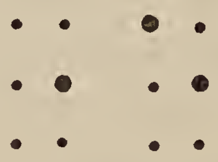


Dots 2, 5, 6 in the initial position of a word with a space preceding it stands for "dis." In the middle position of a word with characters on either side it stands for "dd," and at the end of a word followed by a space it is a "period." When this same character is in the initial position of a group of characters and is followed by the character, dots 3, 4, 5, 6, it is a dollar sign.

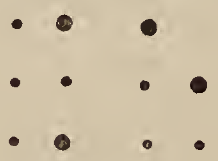
Another example of the multiplicity of meanings assigned to the individual characters is the dots 1, 5 character.



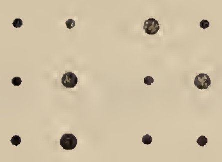
In a word, it is the alphabet letter "e"; when standing alone separated by a space on either side, it is the word "every."



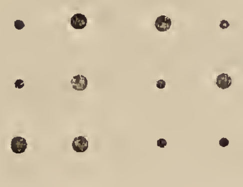
Prefixed by dot 5, it is the initial letter contraction "ever" which can be used as a whole or part word.



Prefixed by dots 4, 6, it is the final letter contraction "ance" which is used as part of a word.



Prefixed by dots 5, 6, it is the final letter contraction "ence" which is used as part of a word.



Prefixed by dots 3, 4, 5, 6, it is the number 5.

Dimensions for Braille Printing

Zickel and Hooper (1957) gave the physical dimensions of the current standard scale for producing braille. The standard measurements of the raised dots in inches are base diameter of dot, .060 in.; height of dot, .017 in.; distance between the centers of adjacent dots within a cell (interdot), .090 in.; distance between the centers of adjacent dots between cells (intercell), .160 in.; distance between the centers of adjacent dots in adjacent lines (interline), .220 in. These measurements, with the exception of diameter and height of dots, have been used as the standard for this country since around 1920 (Latimer).

Some Terms Used to Describe Braille

braille A system of printing and writing consisting of tactually distinguishable, raised dot patterns which represent the elements of a language or other graphic symbology. English braille grade 2, American usage.

braille cell An array of six equally spaced positions, three high by two wide, at which braille dots are located and which are numbered on the left downward 1, 2, 3 and on the right downward 4, 5, 6:

1 ● ● 4
2 ● ● 5
3 ● ● 6

braille character One of the 63 different dot configurations possible within the six positions of the braille cell.

braille reading errors

added dot The identification of a character as having more dots than the stimulus.

ending The addition or deletion or misidentification of the terminal characters in a word.

horizontal alignment The identification of a character having the same number and configuration of dots as the stimulus but on the side of the cell opposite to that of the stimulus.

missed dot The identification of a character as having fewer dots than the stimulus.

reversal The identification of a character having the same number and configuration of dots as the stimulus but rotated in a different direction from that of the stimulus.

vertical alignment The identification of a character having the same number and configuration of dots as the stimulus but in the up-down position of the cell opposite to that of the stimulus.

characteristics of braille Properties of the braille characters and words, excluding the physical dimensions of the dots, which could influence their perception.

equivocal characters Characters that are the same except for their vertical position within the cell.

lower cell characters Characters that have no dots in the one and four positions within the cell.

orthography The standard method of writing braille as prescribed by the AAIB-AAWB Braille Authority. The use of any of the various types of contractions and abbreviations peculiar to the braille system. It is in this latter sense that the word is used in the present study.

TWO

Review of Research on Braille

MANY aspects of braille and its use have been the subjects of research. Those most important to the purposes of this monograph include reading rates, perception in braille reading, frequency of occurrence of braille constructions, and training to increase reading speeds. This research will be described in some detail. Of less importance to the purposes of this monograph is research dealing with extent of use of braille, braille writing, dimensions of braille, techniques in reading braille, relations between braille reading ability and measures of tactual perception, development of measures of braille reading proficiency, and comparisons of braille reading comprehension with that of listening. This research will be reviewed briefly. Next, the lack of research on teaching reading will be considered. Finally, the research on perception will be summarized in relation to the purposes of this research project.

Reviews covering some or most of the research on braille can also be found in Ashcroft (1960), Graham (1962), Hanley (1961), Henderson (1967), Lowenfeld (1963), and Rodgers (1961).

Research in Reading Rates

The earliest studies of braille reading speeds were conducted by Hayes (1918, 1920). Hayes found a mean reading rate of about 64 words per minute (wpm) with rates ranging from an average of 30 wpm in grade 1 to 83 wpm in grade 9. Consequently, Hayes raised the question: "Are we justified in requiring blind pupils to undertake the difficult and tedious process of learning to read with the fingers if we cannot bring their average reading rate above 60 wpm? How many graduates will continue reading if they must read so slowly?" Educators still ask this question.

Hayes' results were obtained with materials embossed in New York Point and uncontracted American Braille, systems of printing no longer in use. Supplanting these systems was braille grade 1½, a moderately contracted system, which was used from around 1920 to 1940. In turn, braille grade 1½ gave way to the present standard braille grade 2 which was adopted as the official textbook code in this country in 1932. With the exception of New York Point, all of these systems used characters formed within the six-position braille cell. [See Merry (1932) for research on teaching contracted and uncontracted braille.]

Researchers reporting reading speeds for braille grade 1½ include Athearn, Campbell, and Lavos (1944), Niday (1939), and Lowenfeld (1945). These researchers reported average reading speeds ranging from 53 to 65.5 wpm for braille readers in grades 4 through 8.

There is a dearth of information on the reading rates of braille grade 2, but what is available suggests that they are not much different from those of the less contracted systems. Athearn, Campbell, and Lavos obtained measures of reading rates of *Reader's Digest* material for 48 students from grades 9 through 11. Their mean rate was 78 wpm.

More extensive data were obtained by Meyers and Ethington (1956) in two studies of braille spacing. Reading rates were obtained for 275 blind children* in grades 5 through 12 at five state schools for the blind and for 167 blind adult volunteers from eight states. For 30 minutes the subjects read sections of a book found to be at the fifth grade level of reading difficulty by the Flesch formula. The mean reading rate for all of the school children was 68 wpm. Extrapolating from a curve of mean reading rates at the various grade levels, the average reading rate for grades 5 through 8 was found to be 63 wpm and that for grades 9 through 12 was found to be 86 wpm. The mean reading rate for the adult readers on the same material was 90 wpm.

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* These data are also reported in Ethington (1956) and Meyers, Ethington and Ashcroft (1958).

In a study of reading and listening in learning among the blind (Nolan, 1966b), reading rates were obtained for 208 fourth-through-sixth grade pupils and for 174 ninth-through-twelfth grade pupils on literature, science, and social studies materials containing about 2,100 words each. The readability of the materials was appropriate to the grade levels involved. The readers came from public school systems and residential schools for the blind in 14 states. The mean reading rates for the different materials at the elementary level ranged from 52 to 57 wpm, and at the secondary level from 66 to 74 wpm. These rates were obtained under instructions to read the material carefully, and students were aware that they were to be tested for comprehension.

Data obtained by the Department of Educational Research of the American Printing House for the Blind gave an additional indication of reading rate. The Gates Basic Reading Test, Type A, Form 1, was given to 321 students enrolled in four residential schools in grades 3 through 12. The mean reading rate of students in grades 3 through 8 was 62 wpm and that for students in grades 9 through 12 was 72 wpm.

Foulke (1962) tested braille reading rates and comprehension of students in grades 6 through 8 for literary and science materials incidental to a study of compressed speech. Passages read contained about 2,100 words. These students read the science material at 57 wpm and the literary material at 70 wpm.

Two recent publications report braille reading speeds far greater than those reported earlier. Lowenfeld and Abel (1967, p. 60) found fourth grade mean reading rates to be 84 wpm for students enrolled in local schools and 72 wpm for students enrolled in residential schools. For eighth grade students, comparable rates were 149 wpm and 116 wpm. These rates appear spuriously high. This is in part a consequence of the ease of the reading test. Students were required to read for one minute the first paragraph of the appropriate level STEP Reading Comprehension Test. No test of comprehension was required. And, in part because of the sampling procedure used, the mental ability of the eighth grade group was considerably above average. Grunwald (1966) implies braille reading speeds of 200 to 300 wpm. No doubt, these speeds are the result of the atypical measure of reading taken in his research.

From the foregoing it should be sufficiently clear that braille reading is a slow process for most users. This slow input rate cannot but be an important factor influencing the use of braille and determining its practicality as a medium for communication. Explanations for slow braille reading rates can probably best be found in studies of the perceptual processes involved in braille reading.

Research on Perception in Braille Reading

While there have been numerous studies of braille reading, the problem of perception, as such, has not been considered, and no research similar to that on print reading described in the Preface has been conducted. The information available on perceptual factors in braille reading has, for the most part, come from studies designed for other purposes and from reading teachers.

Some of the earliest information on perceptual factors in braille reading came from the studies of the Uniform Type Committee (UTC), a group assembled to study the relative merits of the several different punctographic systems in use around the turn of the century. During the course of their work, the committee established an order of legibility of the British braille alphabet characters (UTC, 1913). The interdot spacing and the configurations of the characters were the same as the present standard. Legibility was established by having 53 subjects read 20 lists of the alphabetical characters. Each list contained 160 characters. One hundred of these characters, 25 of the alphabet symbols each appearing four times, made up a common background for all of the lists. The remaining 60 characters were repetitions of the one whose legibility was being studied. Characters that were the same except for position in the braille cell (d and f, p and v, and so on) were tested on the same list. The characters were haphazardly arranged on the lists, but subject to the condition that the experimental unit would not appear more than twice in a row unseparated by other characters. The reading of the lists was timed and the errors recorded. Differences in reading times among the lists were assumed to be due to the presence of the letters being tested. The principal finding was that the number of dots in the characters was directly related to legibility. The most legible characters were those with the fewest dots.

The procedure employed in obtaining the reading times for the characters was admittedly not as refined as was desirable. By including large numbers of reproductions of a single character within a standard context of the other alphabetic characters, the researchers failed to control for the effect of association of letters in the language. Also, placing two similar characters in the same test list precluded distinguishing between them on the basis of reading time and may have increased the error rate of these characters. Even so, it is hard to conceive of these conditions systematically biasing the results to favor the characters with fewer dots.

The UTC also studied the effect of number of dots on the readability of letters and words and the readability of equivocal characters and contractions (1913). In these studies lists of letters and words containing the experimental units were read by large numbers of subjects (usually over 100). The experimental stimuli, common words, were scattered haphazardly throughout a group of words which were standard on all of the lists. Control of the effects of sequence, fatigue, and the like, was achieved by systematically varying the order of presentation of the lists among subjects. The reading was timed and the errors recorded. Analysis of the results revealed that reading times for letters and words increased as number of dots increased, thus substantiating the results of the earlier legibility study. Words containing whole-cell, part-word contractions were read in less time and with fewer errors than the same words in full spelling. Whole-cell, whole-word contractions were read in less time but with more errors than full spelling. Words containing the lower-cell, part-word contractions were read in slightly less time but with more errors than the same words in full spelling. The lower-cell, whole-word contractions required considerably more time and produced many more errors than the words in full spelling. In general, it can be concluded that the whole-cell contractions facilitated reading while the lower-cell contractions retarded reading. However, a word of caution is necessary in appraising these results. Most of these data were obtained from readers using American Braille and New York Point, systems of printing differing somewhat from that currently used. In addition, excepting New York Point, the practice of using contractions in printing was not uniform; hence many of these subjects were more accustomed to full spelling.

The UTC also analyzed the errors made in practically all of their character and word studies (1915). They found the two most prevalent types of errors to be vertical and horizontal alignment in which the vertical and horizontal position of the characters were confused. These errors were followed, in order of importance, by missed dots errors, added dot errors, and confusion "between corresponding characters having the same number of dots," which were probably reversal or mirror image errors.

Despite the considerable implications of the findings of the UTC for understanding perception in braille reading, its work was largely ignored; only a few references to it can be found in the literature. Such was not the case for Burklen's research (1932) on braille reading in Germany. Reflecting the influence of the Gestalt movement with its emphasis upon form, his work was widely quoted in support of the word being the unit of perception in braille reading and in support of the use of the whole-word approach to teaching braille reading.

One aspect of Burklen's research dealt with the legibility of the braille characters. In this study Burklen required 30 school-aged subjects who were skilled braille readers to read 39 single-cell braille characters outlined with nailheads on wood. The subjects wore rubber caps over their reading fingers to reduce sensitivity and the experimenter guided their fingers over the characters. The distance between dots for the braille used was 6 mm, or .236 in., as compared with the .090-in. distance in standard English braille.

In general, the conclusions of the study were that the legibility of the braille characters was related to the configuration of the dots, but not to their number, and that simple geometrical patterns were the most legible. In Burklen's own words: " . . . the dots in touch reading unite into a whole and . . . emphasize the value of the characteristic letter and word form" (p. 50). Summarizing his studies, although he developed no other evidence relevant to the matter, Burklen concluded: "The reading of words and sentences occurs in a comprehensive manner through the apprehension of word forms" (p. 53).

These conclusions were in direct conflict with those of the UTC. In addition, there was little agreement between results of the two studies in the relative order of legibility for common braille characters. The correlation between these two orders of legibility (as computed by the present authors) was .21, which was not significantly different from zero.

No doubt Burklen's unusual procedure was, in large measure, responsible for this lack of agreement. It is likely that his larger, unyielding dots, the greater distance between the dots, and the possible spreading of their sensation by the rubber caps all combined to produce a perceptual situation quite different from that found in actual reading. This difference, of course, would be highly relevant to any application of the findings.

A more recent report of studies of factors affecting braille perception was Horbach's (1951). This work involved a series of experiments conducted between 1923 and 1950 to demonstrate the similarities between print and braille reading. Horbach concluded that the results point to an exact parallel between the two reading processes. However, the methodological deficiencies of his studies make the validity of such conclusions questionable. Among the deficiencies were *(1)* use of too few subjects, *(2)* failure to match subjects or even randomize assignment to groups when making intergroup comparisons, *(3)* repeated use of the same reading content to test various conditions with the same subjects, and *(4)* confounding reading time and response time of subjects in comparing reading times of single letters and letters included in words. Therefore, further review of these studies will not be included here.

Ashcroft's study of errors in oral reading identified some of the orthographic characteristics of braille related to occurrence of errors (1960). Seven hundred twenty-eight subjects in grades 2 through 6 read orally 12 short passages of graded reading difficulty, especially prepared for the study by the investigator. Errors were recorded verbatim as the subjects read individually.

The order of orthographic categories involving the most to the least number of errors was *(1)* short form words, *(2)* multiple-cell contractions, *(3)* combinations of orthography, *(4)* lower-cell contractions, *(5)* upper-cell contractions, *(6)* words in full spelling, and *(7)* alphabet words. The first three categories made up 26 percent of the words and caused 46 percent of the errors. Most of these errors were attributed to the difficulty of remembering the meanings assigned to the various combinations of characters and the infrequent occurrence of these words in elementary school children's reading. Category four (lower-cell contractions) was the most difficult of the single-cell contractions, and failure to determine the level of the characters within the cell was the big problem here. This corresponded to a similar finding by the UTC. The order of difficulty of the categories remained approximately the same for the different grade levels; however, the magnitude of the errors decreased as grade level rose.

The error types according to their frequency of occurrence from most to least were *(1)* missed dots, *(2)* ending problems, *(3)* reversals, *(4)* added dots, *(5)* association, *(6)* gross substitutions, *(7)* vertical alignment, and *(8)* horizontal alignment. Except for ending problems, association errors, and substitutions, the types of errors were the same as those found by the UTC.

Another finding was that the order of difficulty of the error types and the magnitude of the errors changed with grade level of the reader. Reversal and substitution errors decreased as grade level increased, while ending and association errors increased. The former shift indicated that reading became more accurate as the children advanced in grade level. The latter shift reflected the increase with grade level in the number of associations that fit within a given context. The missed dots, added dots, and vertical and horizontal alignment errors remained at approximately the same rank over the grade levels. Regarding the magnitude of errors, there was, in general, a gradual decrease as grade level rose until at the sixth grade there were 41 percent fewer errors than at the second grade. The total number of errors for all grades was 5.3 per 100 words.

Two recent reports have implications for perception in braille reading. Pick, Thomas, and Pick (1966) studied the function of grapheme-phoneme correspondence in braille perception. Their subjects were required to read lists of 60 pseudowords of three to six letters. One half the words were pronounceable and consisted of an initial consonant spelling, a vowel spelling, and a final consonant spelling. An unpronounceable counterpart was constructed for each pronounceable pseudoword. The results indicated that unpronounceable braille pseudowords took longer to read than pronounceable braille pseudowords. Sixty percent of the reading errors involved the unpronounceable pseudowords. About 25 percent of the errors were reversals and 40 percent involved addition or omission of a dot or letter ofen making the pseudoword more pronounceable.

Martin and Alonso (1967) compared reading rates and comprehension of braille material presented in telegraphic style with that of material given in conventional style. Of the 210 pupils participating, one third each read a traditional passage, a medium-length telegraphic version, and a short telegraphic version. Comprehension was tested immediately and after one week. The subjects reading the medium and short telegraphic versions were found to read in significantly less time than those reading the traditional version. However, the reading rate in wpm for the group reading the short telegraphic version was significantly slower (by 40 percent) than those for the other groups. There was little difference among the groups for both immediate and delayed recall.

Research on Training to Increase Braille Reading Speed

Efforts to increase the rate of braille reading through training have been reported by Barraga (1963), Flanigan (1964), Stockton (1965), and Kederis, Nolan, and Morris (1967). Barraga, whose training was directed toward strengthening certain aspects of reading skills, reported essentially negative results. Flanigan and Stockton conducted almost identical studies in which groups of children and adults were paced in their reading performance through adjustment of the rate of presentation of braille in the form of a continuous tape. Both reported significant increases in reading rates. Kederis *et al.* paced reading of groups of children through tachistoscopic means and through use of a variable-speed continuous belt display. While in neither case did over-all significant increases of reading speed result, there was some evidence that superior readers increased speeds when trained on the latter mode of presentation. However, their most impressive finding was that through manipulation of motivational variables, reading speeds could be increased up to 100 percent with no loss in comprehension. This finding cast doubt on the results of Flanigan and Stockton who left motivational variables uncontrolled. The increases in reading speeds found by Ashcroft in a field test of the IBM Reading Machine probably also reflect motivational variation (1959).

Research on Other Aspects of Braille

Research results bearing on the design of point systems for reading and writing can be found in reports of the UTC (1907, 1909, 1913, 1915), Latimer (1920), Overbeay (1938), and Staack (1962).

Frequency of occurrence of the elements of the braille system has been determined by Irwin and Wilcox (1929) and Kederis, Siems, and Haynes (1965).

A question of continuing interest is the extent of use of braille as a medium for reading. Data reflecting use by adults can be found in Josephson (1961, 1963, 1964) and data reflecting use by college students in Carter and Haskell (1961). Jones (1961) and Nolan (1965 and 1967) have studied extent of use by school children. In addition, these studies relate the extent of use to degrees of visual acuity. A report by Rawls (1961) also contains information relevant to braille use by children.

A number of studies have concerned dimensions for braille printing. The UTC (1913), Latimer (1920), Meyers and Ethington (1956), and Calvin and Clark (1958) have studied variations of interdot, intercell and interline distance. They concluded that the current standard dimensions are near optimum. Studies of optimum dot height have been reported by Irwin (1927), Maxfield (1928 pp. 41–2), Meyers and Calvin (1955b), and Zickel and Hooper (1957) who give results on discrimination of differences in dot height. The relationship between braille dot radius and discriminability of dot height is explored in a Master's Thesis by Solomon (1959). With respect to dot shape, both Burklen (1932, p. 9) and Maxfield (1928, p. 41) reported that a rounded conical shaped dot is superior. Meyers and Calvin (1955a) have compared reading speeds for types of interpointed braille.

Other research includes that of Eatman (1942), Weiner (1963), and Nolan and Morris (1965) who have investigated the relationship between certain tactual abilities and braille reading. Tactual and visual means of learning braille were compared by Merry (1931) and Burns (1944). Doriaswamy (1934) reported on reading difficulties of children in the primary grades. Considerable attention has been paid to the mechanics of braille reading, with factors such as hand position, hand dominance, finger movements, finger pressure, regressive movements, and return sweeps being the foci of studies by Maxfield (1925), Smith (1929), Burklen (1932), Fertsch (1932, 1946, 1947), Graseman (1932), Holland and Eatman (1933), Holland (1934), Eatman (1942), Kusajima (1961), and Lowenfeld and Abel (1967). The capacity of all the fingers for reading and the transfer of reading skill from the index finger to the other fingers have been the objects of study by Funchess (1934), Hulin and Katz (1934) and, more recently, Foulke (1964). Comparisons of comprehension from reading and listening have been made by Lowenfeld (1945). Foulke, Amster, Nolan, and Bixler (1964), and Nolan (1963 and 1966b.)* Research on the development of braille mastery tests has been reported by Ashcroft (1960), Lorimer (1961, 1962), Tooze, Woodcock, and Borgeault (1962), and Hanley (1965a and b). Practices in teaching braille writing have been surveyed by Rawls and Lewis (1961). Ricksecker (1932) and George (1961) have compared the reading speed and comprehension of the blind and sighted.

Problems for research in braille have been identified by Nolan (1958), the American Foundation for the Blind (1961), and the Sensory Aids Evaluation and Development Center (1966).

The Lack of Research on Teaching Reading

With the exception of Lowenfeld and Abels' very recent work (1967), the literature on education of the blind contains no published research reports on teaching braille reading. Results of replies by 289 local school teachers and 73 residential school teachers to Lowenfeld and Abel's survey of current teaching practices can best be expressed by quoting their summary:

> Most local and residential schools for the blind began their braille reading instruction in the first grade, after prereading activities had been pursued during the kindergarten year. About one third of the schools started the reading instruction by teaching the braille alphabet, while two thirds began with whole words and/or meaningful sentences. Practically all schools used braille grade 2 (fully contracted braille) from the beginning.
>
> So far as hand-use is concerned, about 85 percent of the teachers encouraged their children to use both hands; the remaining teachers encouraged right-hand-use. Comments of the teachers indicated that they recognize that pupils as they grow older devise their own way of reading regardless of methods taught. More than half of the teachers gave consideration to left-handed pupils.
>
> So far as finger-use is concerned, two thirds of the teachers in residential schools encouraged the use of the index fingers of both hands. Various other combinations of finger-uses were encouraged

* These data are summarized in Morris (1966).

only by two to six teachers each. In local schools, only about one third of the teachers encouraged the use of the index fingers of both hands while the rest encouraged the use of various other combinations of fingers. Sixteen percent of local school teachers and 5 percent of residential school teachers reported that they leave it to the children to use fingers as they prefer.

So far as braille writing is concerned, almost half of the teachers in both types of schools introduced it at the same time as reading, and about one third reported that they do so after some reading skill has been developed. Forty percent of the replies reported that they consider the child's individual level of ability. The braillewriter was almost universally used to teach beginning writing.

Initial instruction in braille reading was given in local schools by resource teachers (51 percent), by itinerant teachers (29 percent), by classroom teachers (9 percent), and by special braille teachers (9 percent). In residential schools this was done by classroom teachers (90 percent) and by special braille teachers (10 percent).

Some additional information was secured from the smaller sample of teachers whose students took part in the tests which were given in connection with the study (20 from residential and 41 from local schools). In local schools, reading books, including preprimers, were introduced either at the beginning of braille reading instruction or after words or sentences were read, while residential schools by a large majority introduced them only after words or sentences were read. Reading instruction was conducted by oral as well as by silent reading. Double-spaced material appeared to be universally used in beginning reading instruction. The use of enlarged cell material has almost disappeared, and standard size braille, which encourages horizontal movement of the reading finger(s) without up-and-down motion, was almost generally used.

As a consequence of lack of empirical data, the practices in teaching braille over the years have appeared to shift with changes in the practices of teaching reading of print (Maxfield, 1928, Chap. IV). In general, it appears that most teachers of braille reading consider the whole word as the unit of recognition, and that the word is perceived on the basis of its over-all shape or form. Binder (1948), discussing the technique of teaching reading, stated: "By learning new words as wholes the child progresses faster in his early attempts at reading." The child should be able to recognize words " . . . when he depends on form alone." Blend (1944), talking about preschool reading training, said: "The children soon learn the shapes of words and groups of words, and later recognize them as whole words." Miller (1940) stated: "Most children, however, learn rather quickly to recognize words as wholes by their shapes. . . ." From which it follows: "The word method seems superior to the others (letter and letter-word methods of instruction)." These statements are representative of the positions of other teachers and indicate the considerable agreement among educators on this question. However, such wide agreement has not always been the case. Merry (1928), discussing the advisability of teaching braille reading by the word method, stated: " . . . in reading by touch, only one character at a time can be covered, and the word is perceived as a series of tactile stimuli." He suggested that the perception of a series of tactile stimuli be studied to determine the appropriateness of the word method for teaching braille reading. Maxfield also raised the question of whether blind children can learn to read by the whole-word method and suggested research in this area (1925). She said that those who are opposed to the word method " . . . insist that it is an impossibility. They say that although these pupils may seem to be reading whole words at once, they are really taking in one letter at a time, in rapid succession. . . . "

To the present authors' knowledge no research of the type suggested has ever been conducted. Some type of resolution of the controversy did occur, though, if the assumption is accepted that the method of teaching reading is indicative of the teacher's conception of the unit of recognition in reading.

Maxfield later suggested the use of the word method in her book on teaching reading to blind children, the only book on instruction in braille reading written in this country (1928). She proposed training pupils to think of wholes before they do the parts. After a discussion of the use of the word method at the Perkins School for the Blind, she stated: "The word method works better than does either of the other two (letter and letter-word methods)." Since that time the majority of teachers of beginning braille reading appear to have adopted a whole-word approach. Lowenfeld and Abel (1967, p. 13), in their survey of current reading instruction, found that approximately 64 percent of the teachers in local and residential schools begin teaching reading with whole words or meaningful sentences.

Some clarification is necessary at this point regarding the description of present-day methods of teaching reading as "letter" or "word" methods. According to Smith (1965, pp. 357–65), almost all current practice is based on use of one of the basal reading series. All such series combine a variety of methods as is indicated as desirable by the findings of the extensive research on print reading activity. According to Smith, who quoted from the *Columbia Carnegie Study of Reading Research and Its Communication,* a national survey conducted in 1962: "Reading instruction in almost all schools starts from a similar basis: basic readers from a graded series are used by 90 percent of first grade teachers and by 92 to 84 percent of second and third grade teachers . . . " (p. 350). This extent of use also appears largely true among the blind. The catalog of the American Printing House for the Blind, in a section appropriate to beginning reading instruction, lists six basic reading series, one set of two pamphlets of stories written especially for the blind, and two series of literary readers. The reading series are the same as those used with the sighted and are merely reproduced in braille. Thus, use of the terms "letter" and "word" methods to describe present reading instruction is misleading. The operations of analysis and synthesis connoted by these terms are, for the most part, combined in current reading instruction.

Summary

In summary very little information on the perceptual aspects of braille reading is available. And the validity of some of that available is open to question. Research producing information of this type has, in most instances, been designed for other purposes. Consequently, the findings have been fragmentary and, at times, conflicting. In the area of teaching, almost no research can be found.

Regarding the basic unit of recognition in braille reading, the conclusions of the teachers and the weight of evidence stemming from research seem to be at variance. The majority of the teachers apparently consider the word perceived by means of its over-all shape or form to be the basic unit on which reading proceeds. On the other hand, practically all of the findings of research applicable to the problem have emphasized the effects of certain characteristics of the individual characters and even the dots on ordinary reading and the recognition of words and characters. These findings do not necessarily mean that the word is not the basic unit of recognition in braille reading, but they do provide a basis for questioning this proposition.

The purpose of the present project is to identify and evaluate some of the characteristics of the characters and words that influence braille reading. A second objective is to obtain information on the basic unit of recognition in reading. Such data will be valuable in assessing the efficiency of the braille system, in developing remedial reading programs, and in guiding instruction of braille reading.

THREE

Summaries of the Nine Research Studies

THIS chapter is designed for the individual who lacks interest in the details of the research or who lacks the skills to read and interpret technical research reports. Hopefully, the short summaries of the studies will provide sufficient understanding of the research and its findings to make the conclusions meaningful and the implications for educational practice and future research clear. The format followed in summarizing the research is that employed by Kirk and Weiner in the volume they edited on research on exceptional children (1963).

STUDY I: Legibility of Single-Cell Braille Characters

Purpose To establish the relative legibility of the 55 braille characters that stand for letters or small letter groups in Standard English braille.

Subjects The 36 residential school subjects included two boys and two girls selected randomly from students in each of grades 4 through 12 whose reading achievement was at the fourth grade level or greater.

Procedure The braille characters were randomly presented until each subject correctly identified each character. The technique used was the ascending series of the method of limits, with each character being exposed initially for a period of .01 sec. Exposure times were increased in .01-sec. steps thereafter until correct recognition occurred.

Results

1. The braille characters differed significantly in the mean times required for recognition.

2. The order of legibility for characters found agreed more closely with that previously established by the Uniform Type Committee ($r = .68$) than that order found by Burklen ($r = .48$).

3. Character recognition time is positively related to the number of dots in the character.

4. Within groups of characters having the same number of dots, those characters with dots most widely dispersed have the shortest recognition times.

5. Characters whose dots fall in the lower two rows of the braille cell require 55 percent more time for recognition than identical characters whose dots fall in the top two rows.

6. Sixty percent of the erroneous responses to the stimulus characters involved naming a character similar in shape to the stimulus.

7. Missed dot errors were responsible for 86 percent of the incorrect responses.

8. Dots falling toward the bottom of the braille cell were missed more frequently than those falling at the top.

9. The order of legibility of the characters was correlated ($r = .46$) with the order of their frequency of occurrence in print.

STUDY II: Effects of Word Length, Familiarity, and Orthography on Recognition Thresholds for Braille Words

Purpose To compare effects of word length, familiarity, and orthography on the thresholds for word recognition by groups of fast and slow readers and to study the relationships between the recognition thresholds for braille words and those for the characters of which they are composed.

Subjects High school students from four residential schools for the blind who read braille with above average comprehension were ranked from fast to slow on a measure of reading speed. Fifteen students were randomly selected from each of the upper and lower thirds of this distribution to comprise the fast and slow reading groups for this study.

Procedure A multivariate design was used to compare the recognition thresholds for 36 braille words that differed in length (3, 5, and 7 characters), familiarity (frequent x infrequent occurrence in print), and orthography (no contractions x contractions). The words were presented in random order under conditions of systematically increasing times of exposure until each subject was able to recognize correctly each word.

Results

1. Recognition times for words increased as they became longer and less familiar and contained contracted braille forms.
2. The effects on word recognition times of increase in word length and decrease in familiarity augmented one another.
3. Orthography interacted differentially with the familiarity variable in that for familiar words, contracted words had the shortest recognition times, while for unfamiliar words, uncontracted words had the shortest recognition times.
4. The effects of this interaction were augmented with the increasing length of the words studied.
5. Fast readers recognized words in significantly less time than slow readers.
6. The single and combined effects of the variable studied were proportionately greater for slow readers.
7. Fast readers recognized individual braille characters in significantly shorter times than did slow readers.
8. The order of legibility of braille characters was the same for fast and slow readers ($r = .80$).
9. Generally, the exposure time required for word recognition was longer than the exposure time necessary to feel all the characters in a word (cover time). Both these times were longer than the sums of the recognition times for the individual braille character (synthetic recognition times) which made up each word.
10. Synthetic recognition times were directly related to word length, but no other variable.
11. The ratio of recognition time to cover time decreased as words grew longer and contained contractions. However, this ratio increased as words become less familiar.
12. Ten percent of the total 1,080 word recognitions required in the study occurred at exposure times which were too brief to allow the subjects to feel all the characters in the word.

13. Recognition of words before all characters were felt rarely occurred for unfamiliar words or three character words. The frequency of occurrence of this phenomenon was positively related to the number of characters in words.

14. Faster readers recognized 20 percent more words before all characters were felt than did slow readers.

15. Fast and slow reading groups did not appear to differ with respect to the types of errors made.

16. Fast readers appeared to differ in IQ from slow readers.

STUDY III: Influence of the Number of Dots and the Position of Dots on Recognition Thresholds for Braille Words

Purpose To establish the relationship between the number of dots in a braille word and its recognition time. To study the influence of the presence or absence of contractions within words upon variations in the number and the position of dots within words. To compare groups of fast and slow readers on measures of IQ and tactual sensitivity.

Subjects Fifteen fast and fifteen slow braille readers at the high school level in three residential schools who were selected as described for Study II.

Procedure A multivariate design was used to compare recognition thresholds of groups of fast and slow readers for braille words that varied in the number of dots contained (varied through five steps of two dots each from 11 through 19), in the position of dots within words (varied between words with a preponderance of dots in the upper part and words with dots evenly distributed), and in orthography (varied between contracted and uncontracted words). Words were equated for familiarity and length. Method of presentation was similar to that for Study II. Measures of IQ were obtained from school records and each subject was given the Roughness Discrimination Test.

Results

1. The mean IQ for the fast reading group was found to be 20 points higher than that of the slow group; however, no difference in tactile discrimination existed between the groups.

2. While the number of dots in a word appeared to be a significant variable, no systematic pattern for this effect could be established.

3. Words with the preponderance of braille dots falling in the upper part were easier to recognize than words with dots more evenly distributed.

4. Fast readers found words containing contractions easiest to recognize, while slow readers found words without contractions easiest.

5. The number of dots within a word, the position of dots within a word, and the presence or absence of contractions within a word were significantly related; however, no clear-cut patterns of relationship were discernible.

STUDY IV: Influence of Braille Contractions upon Recognition Thresholds for Words

Purpose To determine the effects of number of contractions within words, the position of contractions within words, and the position of contractions within the braille cell upon the recognition thresholds for familiar and unfamiliar words.

Subjects Twenty braille readers from grades 9 through 12 who were randomly selected from among 55 such students enrolled in two residential schools for the blind.

Procedure A multivariate design was used to compare recognition thresholds for braille words that varied with respect to number of contractions (one or two), type of contraction (contractions with dots falling in all three rows or contractions with dots falling only in the lower two rows of the braille cell), position of contractions (varied to include words with contractions falling in the initial, middle, and final part of the word), and familiarity (varied between familiar and unfamiliar words). Procedures for establishing recognition thresholds duplicated those of Study II. The number of dots and number of characters in the words were equated.

Results

1. Recognition times for familiar words were shorter than those for unfamiliar words.

2. Correlation between IQ and mean word recognition time for subjects was .57.

3. The effects of the three contraction factors studied varied complexly with each other and the familiarity factor. Some of these interactions were

(a) As the number of contractions increased from one to two, recognition of familiar words became easier and that of unfamiliar words more difficult.
(b) Familiar words with lower contractions were easier to recognize than familiar words with contractions having dots in all rows of the braille cell. The reverse was true for unfamiliar words.
(c) Familiar words with contractions occurring in their initial parts were easiest to recognize, while unfamiliar words with contractions falling in their final parts were easiest.

STUDY V: Effects of Context upon Recognition Thresholds for Braille Words That Vary in Length, Familiarity, and Orthography

Purpose Because the words in studies II through IV had been exposed in isolation, the question arose whether similar effects would result if the words were exposed within the context of sentence structure. This study attempted to answer this question.

Subjects Fifteen fast and fifteen slow braille readers from three residential schools were selected exactly as were those subjects in Study II.

Procedure This study duplicated Study II with the exception that each stimulus word served as the terminal word in a sentence presented auditorily to subjects immediately preceding exposure of the stimulus word.

Results

1. Fast readers differed from slow readers by about 20 IQ points.

2. Fast readers recognized words in significantly shorter exposure times than did slow readers.

3. The effects of changes in word length, familiarity, and orthography upon word recognition thresholds when words were exposed in context were similar to those found in Study II for words exposed in isolation.

4. Variation of these factors singly and in combination resulted in proportionately greater increases in word recognition times for slow as compared to fast readers. Similar results occurred in Study II.

5. In comparison to recognition times established in Study II, context reduced the times necessary for recognition of familiar words and increased those of unfamiliar words.

6. The longer the word, the greater the effects described in item 5 above.

7. In comparison to fast readers, the effects for slow readers of context decreasing reading times for familiar words were much less and the effects of context increasing reading times for unfamiliar words were much greater.

8. For familiar words, the effects of context in reduction of recognition times was much greater for contracted words than for uncontracted words.

9. The presence of context increased the number of words recognized before all characters were sensed from the 10 percent found in Study II to 19 percent; however, these shifts were restricted to the words of five and seven characters.

STUDY VI: Effects of Context Occurring in Continuous Text on Reading Times for the Stimulus Words of Study II

Purpose To study the effects of variations in word length, familiarity, and orthography on reading times for the braille words when they were read within the context of a continuous story.

Subjects Thirteen fast and 13 slow braille readers from grades 9 through 12 of one residential school who were selected in a manner similar to that of Study II.

Procedure A short story was written which contained all the stimulus words of Study II. The oral reading of the story was taped for each subject. These recordings were expanded in time by 185 percent. The time for reading each stimulus word was then measured with an ordinary stop watch.

Results

1. The average IQ of fast readers exceeded that of slow readers by about 15 points.

2. The effects of variation in word length, familiarity, and orthography on reading times for braille words were similar to those found in Study II, with three exceptions:

(a) In Study II the increase in recognition times of words with increases in length appeared to be positively accelerated for all types of orthography. In this study the curve for recognition times of uncontracted words with increases in length appeared to be negatively accelerated.

(b) In this study, a differential reaction to unfamiliar contracted words occurred for the groups of fast and slow readers. Slow readers required considerably more time to read unfamiliar words than did fast. Also, slow readers required more time to read the contracted unfamiliar as compared with the uncontracted than did fast readers.

(c) In Study II the familiar contracted words were recognized in less time than their uncontracted counterparts while among unfamiliar words, contracted words required greater times. In the present study in almost all cases contracted words required longer reading times than uncontracted words.

STUDY VII: Effects of Familiarity, Length, and Orthography of Braille Words on Their Recognition Thresholds at the Elementary School Level

Purpose To compare the effects of variations in length, familiarity, and orthography upon the recognition threshold for braille words for groups of elementary and high school readers.

Subjects The subjects of Study II and 15 fast and 15 slow braille readers in grades 4 through 6 of three residential schools who were selected in the same manner as the subjects in Study II.

Procedure The procedure was identical with that of Study II.

Results The results for elementary readers duplicate those of Study II for high school readers with the following exceptions:

1. No IQ differences were found among groups of fast and slow elementary braille readers.

2. For elementary readers the correlation of IQ with reading rate was −.09 and the correlation of IQ with comprehension was .35.

3. Word recognition times were much longer for elementary grade readers than for high school readers.

4. Variations in word length and familiarity caused disproportionate greater variations in the word recognition times for elementary readers when compared to high school readers.

5. Augmentation of word recognition times resulting in the combined variation of the factors word length and familiarity was much greater for elementary than for high school readers.

6. For unfamiliar words the shift from uncontracted to contracted

orthography resulted in much greater increases in word recognition times for elementary as compared to high school readers.

7. The differences in recognition times for familiar and unfamiliar words were proportionately greater between fast and slow high school readers than between fast and slow elementary school readers.

8. Elementary level readers required significantly greater time to recognize braille characters than did high school readers, although the correlation between the orders of legibility for the two groups was .78.

9. Groups of fast and slow high school readers differed significantly in character recognition times while groups of fast and slow elementary school readers did not.

10. Elementary readers appeared to make more errors in recognition of contracted characters than did high school readers.

STUDY VIII: Braille Word Recognition by Readers of Low Intelligence

Purpose To compare the thresholds for recognition of braille words of groups of low IQ readers from elementary and high schools with those of similar groups of readers of average and above IQ.

Subjects The subjects of studies II and VII, plus 15 elementary (grades 4 through 6) and 15 high school readers from three residential schools. All subjects had IQ scores of 85 or under and showed moderate reading comprehension. The "high school" group was composed of readers of high school age, many of whom were retarded in grade placement.

Procedure The procedure was identical to that of studies II and VII.

Results

1. Low IQ readers as defined by the study comprised 30 percent of the enrollment of the three schools in the elementary grades and 20 percent of the high school enrollment.

2. Mean reading speeds of low IQ readers were the same for elementary and high school groups (50 wpm).

3. There were no significant differences between word recognition times for groups of low IQ elementary and high school readers.

4. Low IQ readers from the elementary grades required 33 percent

more time to recognize words than the normal students of Study VII, while low IQ readers in the high school group required 111 percent more time to recognize words than the normals in Study II.

5. Variations in word length, familiarity, and orthography produced effects in word recognition times for low IQ readers similar to those for normal readers.

6. Contracted words of all types were more difficult for low IQ readers, while normals found contracted familiar words easier to recognize than uncontracted familiar words.

7. The almost total lack of interaction among the factors studied implies that low IQ readers failed to use invariant relationships among the factors as cues for word recognition as done by normal readers.

8. No differences in mean times required for recognition of individual braille characters were found between groups of low IQ elementary and high school readers.

9. No differences in mean character recognition times were found between groups of low IQ and normal elementary readers; however, low IQ high school readers required 89 percent more time than normal to recognize characters than normal high school readers.

10. The differences between recognition times for words and the sum of recognition times for characters within words varied greatly between groups of low IQ and normal readers. These differences for elementary readers were normal, .64 sec and low IQ, 1.15 sec; for high school readers the differences were normal, .42 sec and low IQ, .98 sec.

11. With respect to recognition of words before all characters were sensed, normal elementary readers exceeded low IQ by 23 percent and normal high school readers exceeded low IQ by 3 percent.

STUDY IX: Effect of Character Recognition Training on Braille Reading

Purpose To determine the effects of training for speed and accuracy in braille character recognition on the efficiency of the total reading process.

Subjects Two groups of 12 subjects each were selected from grades 3 through 6 of a residential school. The groups were composed so that they were equated for sex, mean grade, age, IQ, and reading achievement.

Procedure The two groups were pretested on silent reading speed and comprehension, oral reading speed and errors, and character recognition speed and errors. The group selected as experimental then received training in character recognition for 18 consecutive school days. Equivalent postests of all pretested measures were then obtained.

Results

1. Following training, the experimental group, when compared with the control, demonstrated significant decreases in time for character recognition, improved accuracy in character recognition, increased oral reading rates, and decreased oral reading errors.

2. Nonsignificant differences favoring the experimentals were found for increased silent reading rates and increased silent reading comprehension.

FOUR

Conclusions

THE nine studies described in this monograph have touched on a number of the variables that may affect perception of braille words. Although further research on this problem is needed, the authors felt sufficient information had been obtained to permit the formulation of an over-all theoretical description of the braille word recognition process. This formulation not only will provide a basis for development of research hypotheses on the question of word perception itself, but also may provide a basis for the formulation of research hypotheses in the area of reading instruction.

The following discussion is divided into several sections. These deal successively with the questions of the perceptual unit in word recognition, factors in the recognition of braille characters, the process of word recognition, factors affecting the difficulty of word recognition, developmental factors in word recognition, and the relation between mental ability and word recognition.

The Perceptual Unit in Word Recognition

As indicated in the Preface and Chapter One, it has been customary for educators of blind children to conceptualize and describe braille reading as occurring by "the whole word method." This conceptualization parallels that for print reading and probably has its origin in the findings of the research on that medium.

The results of the research reported here indicate that "whole word reading" is not characteristic of the braille readers studied and that the perceptual unit in word recognition is the braille cell. The evidence supporting this conclusion can be found among the results of studies II, IV, V, VI, VII, VIII, and IX. These findings, of course, run contrary to Burklen's conclusions (1932). However, his conclusions are based on studies of character recognition only, while the evidence in these studies stems from a more comprehensive analysis of word recognition which has been confirmed in replication.

The principal evidence for this conclusion stems from the finding that the recognition of braille words requires from 16 to 196 percent more time than the sums of the times required to recognize the individual characters included. In addition, the time required for recognition of words increases as words grow longer. It might be argued that these time differences are accounted for by the time necessary to move the reading fingers the length of the word. However, in establishing recognition thresholds for braille characters, the cue for starting to read was the appearance of a "for" sign in the cell position directly to the left of the stimulus character. Therefore, the value obtained for each character threshold includes the time required to move from an adjacent character. Consequently, these times are automatically included in the sums for the words.

Supportive evidence for this conclusion comes from Study IX which demonstrated that training in character recognition can result in significant increases in accuracy of silent reading, increased speed of oral reading, and decreased errors in oral reading for braille readers in the elementary grades. These findings are in direct contrast with the lack of results of research on training in whole word recognition (Kederis *et al.*, 1967).

Recognition of Braille Characters

As was expected on the basis of experience and previous research, significant differences existed among braille characters in the ease with which they were recognized. The method used for establishing the order of difficulty of characters had adequate reliability as evidenced by the correlation coefficient of .79 between the results of studies I and II. The findings of the studies of order of legibility of characters were in much closer agreement with those of the UTC ($r = .68$) than with those of Burklen ($r = .48$).

While it is not possible to assign priority of importance to the variables, results of the studies emphasized the importance of the number of dots in the cell as well as their configuration as critical factors in character recognition. Here again, results of the study paralleled those of the UTC as contrasted with those of Burklen who concluded that the number of dots is unrelated to legibility of the characters. Burklen's departure from normal reading procedure and use of greater than standard-size cells undoubtedly influenced the order of recognition of the braille characters. Increase in size of the characters doubtlessly served to make form a more distinct quality.

Configuration of the characters within the restrictions of the six-dot matrix also played a role in character legibility. When errors are considered, 60 percent of erroneous recognitions reported by the subjects tended to resemble in some degree the configuration of the stimulus. Characters containing more open space were easier to recognize than those with more dots adjacent regardless of the number of dots included. This characteristic was previously noted by Burklen. The position of the open space also appeared important as was the position of characters within the rows of the matrix. Characters falling in the upper two rows of the cell were recognized more easily than those falling in the lower two rows of the cell. This latter finding had been reported earlier by UTC (1915).

As is the case for other perceptual activities (Bruner, 1961), the recognition of braille characters appears to be based on a probabilistic model of the braille reading environment. Previous experience with the frequency of the occurrence of the dots in the various positions of the cell and with the frequency of occurrence of the various braille constructions in reading affects the interpretation of the stimulus field.

Evidence of this is available from two sources. The first of these is the data on errors in character recognition. The greatest error (86 percent of all) was missed dots where the subjects responded by naming a character with fewer dots than were actually present in the stimulus. The frequency of these errors increased as the position of the braille dots changed from top to bottom of the braille cell—for example, the dots in the top row were missed in 17 percent of the cases, compared with 49 percent for dots in the bottom row of the cell.

There was also a slight tendency for more dots to be missed in the right column as opposed to the left column of the cell. This parallels exactly what was found for a count of the actual frequency of occurrence of each of the dots in the cell (Kederis *et al.,* 1965). The results of this count, which was based on approximately 1,000,000 braille cells in literary material, are given in Table 1. Therefore, it appears that the perception of a braille stimulus is, in part, based on an expectancy of what dots most commonly occur.

TABLE 1 Relative Occurrence of Dots in the Various Position of the Braille Cell in Literary Material

Dot Position	*Proportion of Dots Occurring in Each Position*		*Dot Position*
1	.211	.162	4
2	.176	.163	5
3	.180	.106	6

The perceptual model hypothesized earlier for character recognition also appears to take into account the relative occurrence in literature of the 63 different braille stimulus patterns. A frequency count was made of the different possible patterns as they occurred in parts of 12 different literary works (Kederis *et al.*). Approximately 300,000 words and approximately 1,000,000 braille cells served as the sample for this count. When the character recognition data from studies I and II were ranked and correlated with the same characters ranked according to their frequency of occurrence in literature, the following rank order correlations were obtained: Study I, $r = .24$ and Study II, $r = .46$. The first coefficient is significantly different from zero at the 7 percent level of confidence and the latter is significantly different from zero at beyond the 5 percent level of confidence. These positive relationships imply that relative frequency of occurrence of patterns in literature is related to the ease with which they are recognized.

The Process of Word Recognition

As indicated earlier, the unit in braille word recognition seems to be the braille character. If this is the case, the process of word recognition appears to be a sequential integrative one in which word recognition is the result of the accumulation of information over a temporal interval. Evidence for this comes from the steady increase in mean times found when synthetic recognition times are compared with cover times and these in turn are compared with actual recognition times (studies II, VII, VIII). The differences between the first two indicate that integration of information occurs as the reading finger(s) proceed from character to character. The longer times needed for actual recognition imply that integrative activity continues and closure is obtained after all characters have been covered.

That there are exceptions to this general conclusion is immediately apparent. In many instances words are correctly identified before all the characters are touched. Observation of this phenomenon has probably lent support to the concept of whole word reading. The probabilistic model for perception mentioned earlier can help also in understanding this phenomenon.

It has already been shown that errors in character recognition are correlated with the frequency of occurrence of dot patterns and that the ease of recognition for characters is related to their frequency of occurrence in prose. Previous experience with frequency of occurrence of various structural and grammatical elements of language, in all likelihood, also plays a role in word recognition. Expectancies based on previous experience with language may be involved in word recognition at three levels of perceptual complexity.

At the simplest level, the relative probability of one letter following another most likely is involved—for example, the letter "q" has a very high probability of being followed by the letter "u." As expressed in another way by Shannon and Weaver: "That there are probabilities which exert a certain degree of control over the English language . . . becomes obvious if one thinks, for example, of the fact that in our language the dictionary contains no words whatsoever in which the initial letter j is followed by b, c, d, f, g, j, k, l, q, r, t, v, w, x, or z; so that the probability is actually zero that an initial j will be followed by any of these letters" (1962, p. 102). Additional support for this conclusion is the finding by Pick, Thomas, and Pick (1966) that 40 percent of errors in recognition of braille pseudowords involved omission or addition of a dot or a letter, often making the word more pronounceable.

At the second level of complexity, experience with the frequency of occurrence of sets of letters may become involved in word recognition. The occurrence of prefixes and common stems among words in the English language severely restricts the probability of other letters or combinations following. As letters are sequentially encountered in braille reading, the probability of word recognition is successively increased. If, for example, the first letter in a word to be encountered is "p," the probability for recognizing any specific word beginning with p is quite low. Encountering a second letter "e" increases the probability of recognizing the word. If next the letter "k" is encountered, the probability of recognition becomes much greater because only 14 entries in the 1962 *International Dictionary* contain initial letters in this sequence. The recent findings of Pick, Thomas, and Pick that braille readers read pronounceable pseudowords more rapidly and accurately than nonpronounceable pseudowords supports this conclusion.

The probability of recognizing a word would appear to increase as words become longer. This conclusion is supported by the findings of studies II, VII and VIII, which indicate that long words are recognized before all characters are encountered with much greater frequency than are short words. However, because the probabilistic model is built on the basis of experience, this effect would be at a minimum for unfamiliar words.

At the third and highest level of perceptual complexity, the reader can utilize data stemming from sources other than the word itself for its recognition. A primary source would be contextual material preceding the word. Shannon and Weaver succinctly described this interaction: "At this point an important consideration . . . comes to the front for major attention. Namely, the role which probability plays in the generation of the message. For as the successive symbols are chosen, these choices are, at least from the point of view of the communication system, governed by probabilities; and in fact by probabilities which are not independent, but which, at any stage of the process, depend upon the preceding choices. Thus, if we are concerned with English speech, and if the last symbol chosen is 'the,' then the probability that the next word be an article, or a verb form other than a verbal is very small. This probabilistic influence stretches over more than two words in fact. After the three words 'in the event' the probability for 'that' as the next word is fairly high, and for 'elephant' as the next word is very low" (p. 101).

The results of Study V show that context increases the frequency with which words are recognized before all characters are sensed. As before, word length is positively related to this effect. That experience is a primary factor in providing for this effect is demonstrated by the high frequency of occurrence of this phenomenon with familiar words and its lack of occurrence with unfamiliar words.

If information stemming from contextual material preceding a word contributes to its recognition, it is possible to predict that reduction of this information and removal of grammatical cues stemming from prepositions, articles, adjectives, and adverbs would increase word recognition time and result in an over-all reduction in rate of braille reading. That this is exactly what happens was demonstrated in a recent study by Martin and Alonso (1967). Braille reading speeds of subjects who read a brief telegraphic style version of a passage were significantly slower (by about 40 percent) than were those of subjects who read the passage as traditionally written.

Factors Affecting Time Required for Word Recognition

Generally speaking, recognition times for braille words become greater with decrease in familiarity, inclusion of contractions, increase in length, and shift in dot distributions from concentration in the upper parts of words. Interactions among these variables tend to augment the effects of one another. An exception to this rule, however, can be seen in the effects of the variable familiar-unfamiliar in combination with effects of some of the other variables studied.

An example of this exception is the familiarity x orthography interaction (studies II, IV, V, and VII). Familiar contracted words are easier to recognize than familiar uncontracted words. This situation is reversed with unfamiliar words, in which case uncontracted words are easier to recognize than those which are contracted. The explanation for this paradoxical finding may be found through examination of the relation between the effects of the probabilistic reading model and the sequential integrative nature of the word recognition process. Braille contractions convey more information than do characters standing for single letters. For words already in the vocabulary of the reader, concentration of information in single characters increases the probability for determining what comes next and therefore decreases the time for the integrative process. For words not in the vocabulary of the reader, increasing the information per braille character increases the complexity of the analysis and synthesis that must occur before meaning can be assigned to the group of characters or before the sounds represented by the characters can be vocalized without meaning. If such is the case, increasing the number of contractions in words would reduce recognition times for familiar words and increase recognition times for unfamiliar words. The findings of Study IV point directly to this conclusion. In Study IV familiar words with contractions in the middle or initial position were found easiest to recognize. However, unfamiliar words were easiest when contractions occurred at the end. This finding also agrees with the preceding analysis.

The effects of context on word recognition times are also dependent upon word familiarity. Context facilitates recognition of familiar words but hinders the recognition of unfamiliar words. This effect may also be related to the experiential model the reader has developed. Previous experience determines probabilities for expectations of the sequential occurrence of groups of characters and words. For familiar words such experiences can aid in recognition of words already in the reading vocabulary. However, for unfamiliar words previous experience with the frequency of occurrence of letter combinations tends to lead to error in that false perceptions based on initial letters or parts of unfamiliar words tend to occur. Inspection of errors in Study V confirms this conclusion as well as do Ashcroft's findings that association errors tend to increase with grade level (1960, p. 77).

One other factor studied appears to play a role in word recognition: the number of dots in the word (Study III). However, at this time the specific role of this variable is not clear. Retrospectively, analysis of the words in Appendix B indicates that the authors have confounded number of contractions, number of dots in words, and position of contractions for the experimental words used in this study. This factor may explain the ambiguity of these findings.

It is not assumed that the factors reported in this section exhaust the list of factors that determine difficulty of word recognition. However, it is believed that results of the studies emphasize the changes in difficulty of word recognition that can accompany changes along the continua studied. In addition, the dynamic effects of the interactions among the variables gives insight into the complexity of the braille reading process.

Developmental Factors in Braille Reading

A gross picture of the developmental process in braille reading can be inferred from the findings of studies II, VII, and VIII when related to data available for sighted readers. Generally, the process appears to be the following.

Growth of the factors basic to reading readiness—that is, auditory and tactual discrimination, language development, and breadth of experience—occurs much more slowly with blind children, and basic growth in these areas may still be underway in the upper elementary grades. Consequently, development of reading skills is retarded and reading, even at the upper elementary level, still may proceed in a fairly mechanical manner. Once this basic maturational process has been concluded, the child is free to make more rapid growth through increase in character recognition skills and development of the perceptual model of the reading environment previously described. The ultimate degree to which growth can occur in perhaps both and certainly the latter of these two areas is determined by the child's intellectual endowment. This factor will be discussed in the following section of this chapter.

Evidence for slow maturation of factors basic to reading readiness can be found in Nolan's results (1960) which show growth in basic ability in tactual discrimination still to be underway at the fourth-grade level and the results of Nolan and Morris (1960) which show the great variability among first grade blind children in ability to recognize common household objects by touch. That reading development is still largely in the mechanical stage is indicated by comparing the zero order correlation between reading rate and IQ found for braille readers in grades 4 through 6 in Study VII with the similar correlations ranging from .35 to .65 for sighted children in grades 1 through 6 as cited by Smith and Dechant (1961, p. 89) and the correlation of .57 reported in Study IV for high school students. That reading is not entirely concerned with mechanical aspects of character differentiation is indicated by the findings of Study VII that many of the dynamics of the reading process at the elementary level resemble those of skilled readers and that some words are being recognized before all characters are sensed. However, younger readers are still having difficulties recognizing certain contracted characters. Alignment and reversal errors are greater for this group and differences between synthetic and actual word recognition times are much greater.

Refinement of character recognition skills appears critical for reading progress. Fast and slow reading groups at the elementary level (Study VII) do not differ in this respect, but may differ with respect to the factors important to readiness. Skilled readers at the high school level (Study II) greatly exceed elementary readers in character recognition. At the same time, character recognition skill has become a variable that distinguishes groups of fast and slow high school readers. The importance of refinement of character recognition skills in increasing braille reading ability is also emphasized by the findings of Study IX where for elementary level students, specific training for this purpose was found effective in increasing reading proficiency. Developing ease in character recognition and developing knowledge of the braille code are reflected in reduction of the time needed to integrate the information derived from the individual characters into a word percept. For normal readers this time (recognition time minus synthetic recognition time) is reduced by 50 percent when data for high school readers (Study II) are compared with those of elementary school readers (Study VII).

Mental Ability and Braille Reading

Mental ability is a limiting factor in braille reading as it is in the reading of ink print. Results of studies II, III, V, VI, and VIII show the reading times of high school students for identical material shifted through approximate times of 17, 34, and 52 minutes as approximate mean group IQ shifted through 120, 100, and 75 points. Mean reading rate for the latter ability group was about 40 wpm, or about 44 percent of the rate characterizing the average blind high school senior. This reading rate also approximates that of the second grade sighted reader and is approximately 25 percent of the word rate attained in much normal spoken speech.

The impact of variations in degrees of mental ability appears to fall in three areas critical to braille reading: character recognition, character integration, and utilization of peripheral cues as aids to word recognition. The general effect in the first two areas is to slow performance and in the case of peripheral cues is to reduce the frequency of use.

The effects of variability in mental ability upon character recognition can be discerned by integration of the findings of studies II, VII, and VIII.* For elementary readers of average intelligence (Study VII) median character recognition time was approximately .17 sec with a range of .15 to .25 sec. At the high school level (Study II), for readers of average intelligence (slow group) the median is the same (.17 sec) with a range of .13 to .23 sec. However, for high school readers of higher intelligence (IQ = 121, Study II) median recognition time falls to .09 sec with a range of .06 to .13 sec which has almost no overlap with the range of recognition times for readers of average intelligence. Both these medians and ranges are in extreme contrast with those of the low IQ (75) high school group (Study VIII) which are .24 sec and .21 to .33 sec respectively. These results strongly support the conclusion that speed of character recognition is directly related to the mental ability of the reader.

The interplay between the developmental process and mental ability is clearly demonstrated in the data for character recognition. The similarity of median character recognition time (.17 sec) for groups of elementary readers of normal intelligence (Study VII) and low intelligence (Study VIII) reemphasizes the point made earlier that factors other than mental ability appear to exercise predominate influence in the early phases of learning to read. However, as reading skills develop, intelligence plays a more important role, one aspect of which is facilitating a reduction in character recognition times (Study I). Readers lacking in mental ability fail to improve in character recognition as evidenced by the findings for the high school readers of Study VIII.

In addition to slowing character recognition, low mental ability appears responsible for increasing the amounts of time required to sequentially integrate the information derived from the individual characters in order to arrive at a word percept. The evidence supporting this conclusion is found in comparisons of the differences between the actual word recognition times and synthetic word recognition times for groups varying in mental ability. These average time differences for readers of normal mental ability are .42 sec for high school readers (Study II) and .64 sec for elementary readers. Similar differences for readers of low mental ability are .98 sec for high school readers and 1.15 sec for elementary readers. These data indicate that the time required for low IQ readers to integrate information obtained from the characters within a word is about twice that required by normal readers regardless of grade level. The influence upon the developmental process of variations in mental ability is again demonstrated by the fact that in the years between elementary and high school, integration times are reduced about 50 percent for readers of normal intelligence and only 20 percent for readers of low intelligence.

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* The findings of Study I are inapplicable here because of differences in the mode of presentation of the stimulus materials.

The evidence supporting the conclusion that readers of low mental ability rely less upon peripheral cues in word recognition is not so clear as that presented for the two previous conclusions concerning effects of mental ability. It is true that for low ability readers significant interactions among the major variables word length, orthography, and familiarity almost disappear. This implies that subtle cues arising from combinations of these variables are useless to the low ability group. Reversal of the direction of the orthography x familiarity interaction in that contractions interfere instead of aid in the recognition of familiar words also supports this thesis. The best evidence for this conclusion would be found in large differences between the ability groups in the number of words recognized before all words were sensed. Such evidence is available for the elementary readers in that normals exceeded low ability readers by 23 percent in this respect. However, these differences shrink to about 3 percent in favor of normal high school readers when compared to low IQ high school readers. It should be reemphasized that this phenomenon was restricted almost entirely to the familiar words. Since these words were among the first 5,000 words in frequency of occurrence, it may be that they were learned by the low ability group through the brute force of repeated exposure.

The very low mean reading speeds of 50 wpm shown by elementary readers with IQs of 85 or below approximate reading speeds attained by sighted readers at the second grade level (Harris 1947, p. 449). Data from Study VIII reveal that, for this mental ability group, reading rates do not develop beyond this point even in high school. These findings suggest that below a certain level of mental ability, braille ceases to be an effective medium for educational communication. The results of the studies reported in this monograph make explicit the greater complexity of the braille reading process as compared to print and suggest its greater difficulty. These facts, in turn, imply that the intellectual cut off point for serious consideration of reading as an educational vehicle may be much higher for braille than for print. Consequently, the strong emphasis placed on development of braille reading skills for almost all blind chldren may, for those in the lower ranges of mental ability, impose a severe and, in many cases, a fatal educational handicap.

Summary

The braille character is the perceptual unit in braille word recognition. Braille characters differ widely in ease of recognition which is affected by such factors as number of dots, configuration of dots, the amount of open space within the character, the frequency with which the character appears in print, and the frequency with which each dot position occurs in braille printing.

The process of braille word recognition is a sequential integrative one in which word recognition is the result of the accumulation of information over a temporal interval from sensing the braille characters. Peripheral cues also play a part in word recognition. These are derived from preceding context, experience with the probabilities with which letters and letter groups follow one another in print, and knowledge of the grammatical properties of the language. Many factors are related to the time required to recognize words. Among these are familiarity, orthography, length, number of contractions, position of contractions, number of dots within a word, and distribution of dots within a word. The effects of these factors on word recognition times interact in complex ways in some instances offsetting one another and in others facilitating one another.

The rate of development of braille reading skill appears to lag considerable behind that for print. Evidence from other research implies this is the result of retarded development in readiness. The mechanical aspects of reading (character recognition and knowledge of the braille code) are still problem areas in the upper elementary grades. Once these are mastered, readers are free to increase character recognition skills and to develop the perceptual model of the reading environment so necessary to skilled reading.

Mental ability is a significant factor in the development of braille reading skill. The speed with which characters are recognized and words are recognized is directly related to mental ability. In addition, level of mental ability appears to be directly related to the complexity and validity of the perceptual model of the reading environment which is developed. The evidence of the study strongly suggests that for students whose IQ is below 85 braille is an extremely inefficient medium of communication and that the necessity of mastering it may constitute an additional educational handicap.

FIVE

Implications of the Research

THE findings of this research project and its resulting theory of the braille reading process have widespread implications. The purpose of this chapter is to explore some of these implications for the areas of education, research and tactual code development.

Education

Results of the studies have implications for many facets of education related to development of reading skills. These range in time from the preschool period to at least early high school.

The all-pervasive influence of word familiarity upon word recognition emphasizes the often-voiced plea for stress on concept and vocabulary development. This stress should begin in preschool years with emphasis on spoken vocabulary development on the basis of broad, first-hand, concrete experience and should continue with stress on both spoken and reading vocabulary development throughout the school years. Over this span of time emphasis can, of course, shift from development based on first hand, concrete experience to experiences of an abstract verbal nature.

In the preschool and primary years tactual perceptual development of all kinds should be stressed. Starting with gross examination of real objects which can actually be part of vocabulary development exercises, training should proceed through familiarity with gross variations, both two and three dimensional, in texture and form. As training continues, introduction of finer discriminations can be paralleled with experiences calling for the orderly categorization of materials according to their variety of attributes. This training would include the socialization of perceptual activities through stress on manipulations arbitrarily requested by the teacher. At the terminal end of this process should occur training in perception of punctographic forms. This might proceed from gross perception of previously learned two-dimensional forms expressed in terms of diminishing numbers of points (for example, a square produced initially large by dotted lines reduced to a square represented by four points) to actual discrimination of the forms of the braille characters. At this level of experience, no literal meaning need be attached to the characters. This final stage, of course, reflects the importance of character recognition as revealed by the research.

Since it appears that the character is the perceptual unit in reading and that word recognition is the result of sequential integration of information reflected by the characters, it seems realistic to emphasize character recognition as well as word recognition in the early stages of reading instruction.

The difficulties in word recognition imposed by use of contractions, particularly lower-cell forms, have implication for the design of early reading materials. Learning to read may be conceived as composed of a relatively short stage where the child learns that spoken words can be represented by tactual forms and a relatively lengthy stage where he learns the code for this purpose and develops skill in its use. Because contractions and multipurpose use of the same character forms represent ambiguities beyond those normally found in the English language, it appears desirable to design initial reading materials which would minimize usage of these forms. Once the concept of reading had been grasped and some rudimentary skill developed, transfer to the more complex material could occur. Writing special materials of this nature would also provide an opportunity to get away from the "look, look" approach and emphasize experiences common to visually handicapped children.

As the complexities of grade 2 braille are encountered, constant monitoring of character recognition skills and knowledge of code meanings seems critical. To some extent, this could be accomplished by the tests mentioned in the review of literature. Prompt remediation of errors, along the lines utilized in Study IX, appears critical for reading skill development.

During the elementary years, reading development curves for individual children should be accumulated. When rate of development of reading speed and comprehension departs significantly from the rates required by the information gathering burden imposed by grade level, the student's information gathering capacity should be supplemented by use of auditory materials. Emphasis on braille as a record-making and summarizing technique should be continued.

The use of previous context, knowledge of sentence structure, and knowledge of word forms and letter sequences as cues in word recognition have implication for instruction in the upper grades. Such subjects as grammar and morphology of words should receive added stress for braille readers. Practice in anticipating word endings and word sequences would appear desirable.

The research findings also have implication for teaching braille to the adventitiously blind who have previously learned to read print. This task appears composed of at least three parts: shift from a visual to a tactual mode, shift from a gross perceptual system (whole word or phrase) to a fine perceptual system (character), and learning of a different code for spelling, and so on. Approaching these transitions in a step by step fashion rather than in a brute force frontal confrontation appears desirable. First stress on tactual discrimination with emphasis on braille forms semiindependent of literary meaning appears desirable. Next, transfer to tactual reading with stress on the more fragmented perceptual process should occur. The final stage should consist of learning the new code for writing. Doubtlessly, these three stages can be overlapped to some extent—for example, one-cell, whole-word contractions would be relatively simple to introduce at the second stage.

Tactual Codes

A number of the findings of the research have implications for the formation of tactual codes. Because the number of dots in the punctate character was found directly related to its legibility, increasing the number of dots per character as in "nine-dot braille" can only increase reading time and difficulty. The same thing appears true for increasing the complexity of a code through use of contracted and abbreviated forms or increasing the number of forms of characters included. However, for areas of learning (science and mathematics) where reading populations are drawn solely from the upper ranges of intellectual ability, codes utilizing more dots and shortened forms may have utility.

It is extremely desirable that design of new tactual codes take into account the relative frequency of occurrence of the elements of the language to be coded. Computers make such analyses quite feasible for most languages. Data on relative frequency enable the code designer to rank language elements according to frequency of occurrence and assign the simplest tactual symbols to the most frequent. This makes reading easier. In addition, frequency data enable the code designer to approximate the point where the addition of contracted forms no longer results in significant reduction in length of material. For example, using data from Kederis *et al.* (1965), the authors were able to estimate that omission of 63 of the contracted forms included in the current code for grade 2, English braille would result in an increase in total length of written materials of less than 1 percent.

Research

The studies completed under the project, while revealing, identified many gaps in our knowledge about braille reading as well as pointing out new directions for research. One such deficit is lack of a clear picture of the pattern of growth of braille reading speed and comprehension over the ranges of grade, chronological age, and mental ability. Such curves could contribute much to better understanding of the research results generated by this project.

Although Study II and its complements provide a gross picture of the interactions among the variables word length, word familiarity, and orthography, many of the details need clarification. Study of these variables and their interactions over finer gradations of the continua of each would be useful. For example, study of word length using eight categories ranging from two through nine characters might be revealing. Combining this with study of more discrete degrees along the continuum of frequency of occurrence for words seems desirable. Relating these variations to orthography along the dimensions number of contractions and position of contractions should clarify many of the ambiguous areas in the current findings and their interpretation.

The importance of the number and distribution of dots in words was revealed only tentatively in the present research. These variables could profitably be studied in relation to the three factors mentioned above.

Refinement of the data describing the relative legibility of the braille characters is needed. The specifications for the tachistotactometer assumed that no braille character could be recognized at exposure times below .01 sec. Experience has proved this assumption false. Consequently, devices of this nature with more rapid response capability must be designed before more accurate character recognition times can be established. Once available, these data should be utilized for further comparison of actual and synthetic recognition times for words.

The developmental process in braille reading needs much more thorough study. While in part this can be achieved through definition of the growth curves for reading speed and comprehension mentioned earlier, study in more depth is needed. Studies using the techniques developed in this project but extended into the lower grades using simplified materials appear fruitful. Certainly, the character recognition studies should be extended downward. Error analysis as initiated by Ashcroft (1960) and diagnostic testing as initiated by Woodcock and Bourgeault (1964) and Hanley (1965a) appear useful approaches to this end. Development and experimental use of a braille analog of the Illinois Test of Psycholinguistic Aibility should prove fruitful.

While the importance of varying degrees of mental ability for development of braille reading skill has been clearly indicated, the ramifications of this need further exploration. For example, is there a level or range of mental ability where listening has greater payoff than braille reading as a communication medium?

More thorough exploration of basic tactual perceptual processes and their relation to reading development is needed.

Confirmaton of the effects of character recognition training on the development of reading skills within the elementary grades would be useful. Sets of materials should be specifically designed for this purpose and empirically validated. The same can be said for all the procedures suggested earlier as implications of the research for education. This is particularly critical for the early stages of learning to read.

One aspect of braille reading largely ignored in the theoretical development resulting from this project is the practice of semiindependent use of two hands. The utilization of this practice by the reader would certainly appear to cause a shift in the relative importance of central and peripheral cues to the word recognition process. Study is required.

In the current project and in previous studies in the field, little attempt has been made to relate findings in research on braille reading to research findings and applications from the more general areas of communications (for example, information theory and signal detection theory) and psycholinguistics. The probability of developments in these fields contributing to understanding of the braille reading process is great.

Developments in computer technology hold great promise for study of braille. Frequency studies of grade 2, English braille (for example, Staack, 1962 and Kederis *et al.,* 1965) need to be expanded and these techniques extended to other codes such as the Nemeth code. Future code development should be based, to a large extent, on such data.

For the student of braille reading, the horizons to be explored are broad and far reaching.

PART TWO

SIX

Study I: Legibility of Single-Cell Braille Characters

A MAJOR question unanswered by previous research concerned the factors related to the relative difficulty of character recognition. Previous studies (UTC, 1913; Burklen, 1932; Horbach, 1951) used methodologies that were relatively gross. Use of more refined apparatus and experimental techniques was expected to provide data that would help answer the question regarding significant factors in character recognition. Therefore, this problem was chosen for the initial research effort.

The purpose of the study was to establish the relative legibility of the 55 braille characters that stand for letters or small letter groups in Standard English braille. The criterion selected for comparative legibility was the minimum time required for recognition of each character or the recognition threshold.

Subjects

The 36 subjects in the experiment included 18 male and 18 female, blind, skilled braille readers in grades 4 through 12 at the Kansas, Kentucky, and Tennessee state residential schools for the blind. Two girls and two boys were randomly selected from each grade. The subjects' reading skill was determined by their score on Gray's Standardized Oral Reading Test, Grade 2 Braille. Skilled readers were considered to be those who scored at the fourth grade level or above because a study by Fertsch (1946) showed that the mechanical habits of reading of the blind became established by the third grade. If a reader failed to reach the fourth grade level of reading skill, additional students were randomly selected until one was identified who met this requirement. Subject data can be found in Table 2.

TABLE 2 Mean Age, Reading Score, and IQ for the Four Subjects Selected at Each Grade Level

Grade Level	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Age (in yrs.)	9.50	10.75	13.00	12.75	13.75	13.25	16.75	17.25	19.00
Grade equiv. reading score	4.5	7.3	5.9	8.1	10.3	10.7	8.0	11.3	6.1
Intelligence IQ quotient	99	115	92	99	126	130	105	111	113
Number of subjects	4	4	4	4	4	4	4	4	4

Method

DESIGN Each subject was required to recognize each of the 55 braille characters. These data were then analyzed in an analysis of variance design of three dimensions—that is, characters, sex, and grade level. This design not only provided a test for differences in recognition thresholds for braille characters, but also allowed tests to determine whether such differences were related to the sex of the subjects or their grade level.

APPARATUS The recognition times for the characters were obtained by means of a tachistotactometer, an instrument that exposes braille characters and words to a reader for controlled periods of time. The braille was embossed on special plasticized paper and pressed up through a screen in which there is a line of holes that correspond to 36 braille cells. Plasticized paper was used to insure adequate relief and greater durability of the dots. The spacing between dots and the height of dots exposed above the surface of the reading screen was approximately what is considered standard by the American Printing House for the Blind. The period of time the material could be exposed ranged from .01 sec to 10 min in steps of .01 sec. Average exposure time error was 2 percent of the nominal value. For a picture of the apparatus see Figure 1.

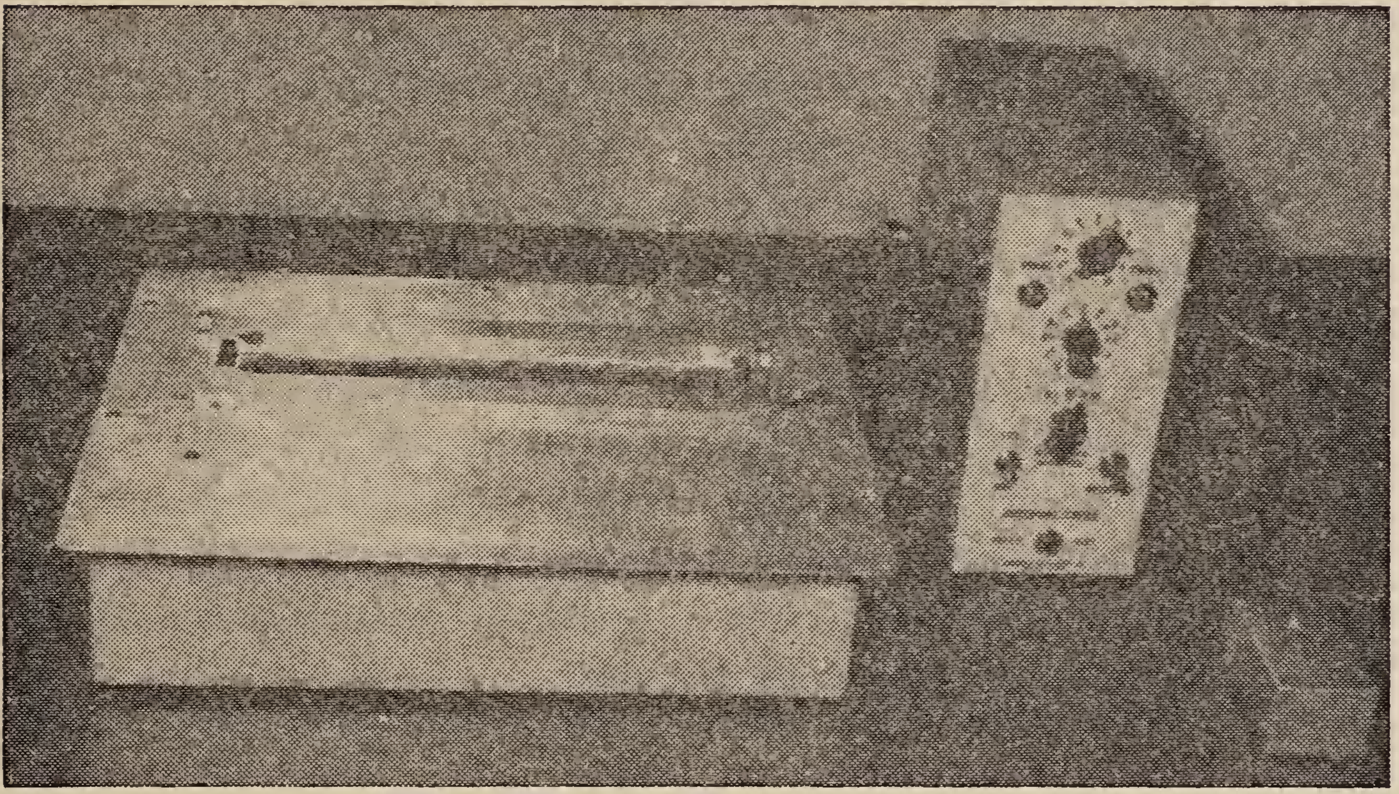


FIGURE 1. *Tachistotactometer and Auxillary Timing and Control Equipment*

MATERIALS The stimulus materials were the 55 braille characters randomly ordered on seven slips of the plasticized paper. Six of the slips contained eight characters; the other contained seven. There was a separate set of materials for each subject. Also, the random order for sequential presentation of the slips was different for each subject. The random orders were obtained from a table of random digits.

PROCEDURE For each subject the experiment consisted of four one-hour sessions held on each of four consecutive days. During the first session the subject's level of reading ability was determined, instructions for the task were given, and recognition thresholds were established for eight of the stimulus characters. During the other three sessions thresholds were determined for the remainder of the stimuli at the rate of approximately 16 each session.

In the instructions the operation of the machine and the procedure were explained, and the subject was told to " . . . try to recognize the sign just as you do when reading. Do not spend too much time trying to figure out what the sign is. Simply name it and move on to the next position. If you aren't sure about the sign I want you to guess; this is very important."

The method of minimal changes was used for obtaining the recognition thresholds (Guilford, 1954, pp. 101-17). Only the ascending series of presentations prescribed by the method was used as follows. Initially, all characters studied during each session were successively exposed to each subject for a time interval well below that required for recognition. The exposure time was then increased by .01 sec and all characters were presented again. This systematic increase of exposures in steps of .01 sec was continued until all of the characters were recognized to criterion. The criterion was three correct identifications out of four successive exposures. As the characters were identified to criterion, they were omitted from subsequent exposures. When half of the characters used during a session were identified to criterion, the order of presentation of the remaining unidentified characters was changed from a successive one to a haphazard one. This change was used to prevent the use of position as a cue.

Results

For each subject the time taken as the character recognition threshold was the time of the first of the four exposures during which the character was identified three times. The relative legibility value of a character was an average of all of the subjects' recognition threshold times for that character. Table 3 shows the average recognition times in hundredths of a second for each of the characters. Many of the characters in the table have the same mean recognition times; however they appear, and are, ordered because the sum of their recognition times differed.

The range of recognition times for all the characters was .01 to .59 sec and the mean was .07 sec. Therefore, the distribution of the recognition times was positively skewed. In order to make the data amenable to analysis of variance techniques the recognition times were transformed into log values (Kempthorne, 1952, pp. 153-8). This transformation normalized the distribution, and a characters × grade level × sex analysis (Lindquist, 1953, p. 281) produced the results shown in Table 4.

TABLE 3 Mean Recognition Times of 55 Single-Cell Braille Characters

Char.	*Mean*	*Char.*	*Mean*	*Char.*	*Mean*
E	.02	wh	.05	ble	.08
A	.02	en	.05	gg	.08
I	.02	J	.05	was	.08
C	.02	G	.05	and	.09
K	.02	H	.06	Z	.09
st	.03	his	.06	dis	.09
B	.03	ar	.06	Y	.09
com	.04	gh	.06	P	.10
ch	.04	X	.06	with	.10
in	.04	L	.06	W	.11
sh	.04	S	.06	ed	.12
ea	.04	N	.06	T	.12
D	.04	V	.06	ou	.14
M	.04	ow	.07	R	.14
U	.04	th	.07	er	.15
O	.04	F	.07	of	.16
con	.04	the	.08	Q	.18
bb	.05	ff	.08	for	.19
ing	.05				

Only the main effect of characters and the characters × sex interaction were significant, the former beyond the .01 level of confidence and the latter at the .05 level. No explanation appeared available for the characters × sex interaction. The male subjects identified 31 of the 55 characters in slightly less time than the females.

Rank order correlations of the order of legibility for characters common with the UTC's (1913) order and Burklen's (1932) order yielded coefficients of .68 and .48, $p < .01$, respectively. Thus, there was considerably more agreement with the UTC's findings than with Burklen's.

The characters were grouped according to the number of dots they contained and a simple analysis of variance computed on the recognition times. The mean recognition times for the groups are presented in Table 5. The mean times for the groups evidenced a somewhat systematic increase of the order of .03 sec as the number of dots increased from two to six. Results of the analysis showed that the means for the groups differed beyond the .01 level of significance. Thus, the number

TABLE 4 Analysis of Differences Among Recognition Times of Characters with Subjects Classified by Sex and Grade Level

Source of Variation	*DF*	*MS*	*F*
Between subjects	*35*	*1.4985*	
Sex	1	.0200	
Grade level	8	1.7637	1.29
S × G	8	1.7212	1.26
Error	18	1.3638	
Within subjects	*1,944*	*.1849*	
Characters	54	2.4625	20.52[a]
C × S	54	.1666	1.39[b]
C × G	432	.1176	
C × S × G	432	.1159	
Error	972	.1200	
Total	1,979	.2081	

[a] $p \leq .01$
[b] $p \leq .05$

of dots in the characters appeared related to their legibility, and the findings and conclusions of the UTC were confirmed.

In another analysis of variance the characters were grouped by number of dots and the size of the space between the dots—that is, greater distance, where one or more of the dots in a character was separated from the others by more than the standard distance, and standard distance, where each of the dots in a character was immediately adjacent, either horizontally or vertically, to another dot. The means for these groups can be found in Table 6.

All effects in the analysis were significant, the number of dots beyond the .01 level and spacing and the interaction beyond the .05

TABLE 5 Mean Recognition Times of Characters Grouped According to Number of Dots

Dots					
1	2	3	4	5	6
.030	.033	.058	.091	.128	.190

level. These results indicated that a greater space between the dots facilitated the recognition of some of the characters. However, this effect was not pure, and the groups differed in other respects. One of these was the presence of more lower cell characters in the standard distance group and another was a certain arbitrariness within the five-dot category.

TABLE 6 Mean Recognition Times of Characters Classified by Number of Dots and Distance Between Dots

	Number of Dots in the Cell			
	2	3	4	5
Greater distance	.032	.051	.085	.093
Standard distance	.037	.065	.093	.165

With these variables removed, however, there still appeared to be a definite effect due to the space between the dots, and probably as important as the space itself was the location of the space. Recognition times for the characters having a greater space or opening at the top and/or the left of the cell were compared with those having a greater space at the bottom and/or right. The two dot characters were not included because they did not lend themselves well to such a schema. The classification is presented in Table 7.

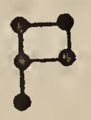
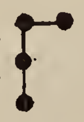
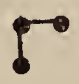
It was found that the characters having a greater space at the bottom and/or right required 22 percent more time to be recognized. In an analysis of variance with dots as another treatment this difference was significant at the .05 level of confidence. Thus, the subjects appeared to benefit from attending to the upper, left-hand portion of the braille cell.

Another characteristic of braille examined for its effect on recognition time was the position of the character in the cell—that is, whether the ten lower-cell characters in the study were recognized in the same amount of time as their counterparts in the upper part of the cell. It was found that the lower-cell characters required 55 percent more time to be recognized. This result was in accord with similar findings by the UTC.

TABLE 7 Recognition Times for Characters Classed by Number of Dots and Location of Open Space in Cell

Number of Dots	*Location of Open Space*			
	Top-Left		Bottom-Right	
3	D	1.29	F	2.47
	J	1.93	H	2.11
	sh	1.49	M	1.32
	ing	1.76	U	1.32
	wh	1.71	S	2.17
	ar	2.15	gh	2.32
	O	1.40	ow	2.64
4	th	2.41	P	3.47
	ble	2.81	V	2.26
	N	2.32	ed	4.45
	Z	3.41	the	2.83
	W	4.08	R	5.17
	T	4.41	ou	4.94
5	er	5.35	Q	6.50
	with	3.60	of	5.90
	Y	3.39	and	3.31
Mean		2.72		3.32

An examination of the incorrect responses was made by tabulating the characters confused with the stimuli by more than 25 percent of the subjects. The results are presented in Table 8. The influence of the shape of the characters on legibility was obvious. Approximately three fifths of the confusors were similar in shape to the stimuli. Here similarity of shape referred to a likeness between some of the characters based on the general outline of their dot configurations. The general outline was considered to be that which was obtained when the dots in the characters were connected by lines with the extent of the characters partially disregarded. For example

"q" (), "p" (), and "f" ()

were considered as corner forms having a similar shape.

Among the confusors almost all of the error types mentioned by the

TABLE 8 Most Frequently Confused Braille Characters

Stimulus	Confusor	Stimulus	Confusor
for ⠿	⠛ ⠟ ⠃ ⠶ ⠋ ⠚ ⠻ ⠯	V ⠧	⠓ ⠣ ⠧
Q ⠟	⠋ ⠏ ⠛ ⠃ ⠊ ⠍	X ⠭	⠍ ⠬ ⠥
of ⠷	⠧ ⠓ ⠳ ⠛ ⠗ ⠇	G ⠛	⠙ ⠋ ⠓ ⠉
er ⠻	⠹ ⠙ ⠛ ⠫ ⠺	dis ⠲	⠙ ⠒ ⠉
with ⠾	⠼ ⠚ ⠞ ⠛ ⠿	was ⠴	⠔ ⠴
Y ⠽	⠭ ⠝	ff ⠖	⠋ ⠔ ⠊
and ⠏	⠭ ⠫	ow ⠪	⠎ ⠫
R ⠗	⠓ ⠋ ⠃ ⠇ ⠕	F ⠋	⠉ ⠁ ⠊ ⠃
ou ⠳	⠱ ⠑ ⠙ ⠣ ⠓ ⠢	gh ⠣	⠑ ⠢ ⠡
ed ⠫	⠩ ⠋ ⠍ ⠣ ⠑	S ⠎	⠊ ⠔
T ⠞	⠚ ⠊ ⠎ ⠜ ⠄	ar ⠜	⠊ ⠔ ⠌
W ⠺	⠚ ⠙ ⠃	L ⠇	⠃ ⠅ ⠃
P ⠏	⠋ ⠍ ⠃ ⠎ ⠊	his ⠦	⠓ ⠢
Z ⠵	⠱ ⠕ ⠡	H ⠓	⠛

TABLE 8 Most Frequently Confused Braille Characters (cont'd)

Stimulus	Confusor	Stimulus	Confusor	Stimulus	Confusor
gg ⠶	⠛	J ⠚	⠊ ⠉	O ⠕	
ble ⠼	⠜ ⠚ ⠬	ing ⠬	⠌ ⠥	U ⠥	⠡
the ⠮	⠪ ⠎	wh ⠱	⠑	M ⠍	⠅ ⠩
th ⠹	⠙	sh ⠩	⠡	D ⠙	⠉
N ⠝	⠕ ⠜	in ⠔	⠊	bb ⠆	⠃
con ⠒	⠉	en ⠢	⠑	ch ⠡	⠑
com ⠤	⠒	B ⠃	⠁	st ⠌	
K ⠅		C ⠉	⠁	I ⠊	
E ⠑		ea ⠂	⠁	A ⠁	⠉

UTC (1913) and Ashcroft (1960) were found. The most frequent type of erroneous response was missed dots which occurred in 86 percent of the responses. This is the error where the character named by the subject has fewer dots than the stimulus. Its occurrence was almost exclusively confined to the three-and-more-dot characters with the characters containing more dots having proportionately more of these errors. The two- and one-dot characters were relatively free of this type of error. The other types of errors according to their frequency of occurrence were alignment errors, added dots, and reversals. Together they accounted for the other 14 percent of the errors, and were found almost exclusively among the three- and two- and one-dot characters. This restriction was due, in part, to the presence of the lower-cell characters among the three-, two-, and one-dot groups.

Another aspect of the missed dot errors was the frequency with which dots in the six positions within the braille cell were missed. This information can be found in Table 9.

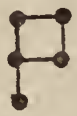
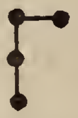
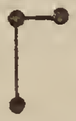
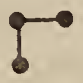
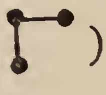
TABLE 9 Proportions of Total Number of Missed Dots by Dot Position

Dot Positions	*Proportions of Missed Dots*	*Dot Position*	*Proportions of Missed Dots*
1	.07	4	.10
2	.17	5	.17
3	.25	6	.24

The number 3 and number 6 dots were the hardest to recognize. They were missed in 49 percent of the cases. The number 2 and 5 dots were next in order of difficulty, being missed 34 percent of the instances, and the number 1 and 4 dots were missed least of all, 17 percent. Between the two sides, the dots on the right were missed in 2 percent more instances than those on the left. These results partially corresponded to what the UTC found and also substantiated the before mentioned finding of the tendency by the reader to attend to the upper and left-hand portion of the cell.

Discussion

The results of the present study emphasize the complexity of the interactions of the various factors which, within the confines of a 2 × 3 array, determine the legibility of braille characters. It was found that the number of dots, the distance between dots or presence of empty spaces in the cell, and the position of dots all influenced legibility. Burklen's emphasis on the effects of form on legibility was partially justified. The location of an empty space in the cell, the shape or configuration of the dots, and the location of configurations of dots all influenced the legibility of the characters. Thus, the question of which characteristic is the more important now becomes one of how all the characteristics interact to contribute to legibility.

The effects of these different attributes of braille characters which influence perception have not yet been specifically determined. However, a little light can be thrown on the meaning of the interaction between number and configuration of the dots by examining them in terms of the most frequent error type, missed dots. Missed dot errors occurred almost exclusively within the three-, four-, and five-dot characters and rarely among the one- and two-dot characters. Three-dot characters had less than half as many missed dot errors as either the four- or five-dot characters. Furthermore, it was within the three-dot characters that practically all the other error types occurred. The relation of these findings to character shape is simplified by the fact that what can be considered as shape in the braille characters is confined to the three-, four-, and five-dot characters. Among these groups there is a probability relationship which leads to a greater expectancy that a character having a given shape is a three-dot character. Specifically, to the five-dot characters a dot cannot be added and the shape retained, and among the four- and three-dot characters the number of alternatives or choices of symbols being similar in shape is greater by a factor of 3 to 1 in the group of characters having fewer dots. For example, the "q" character (), which contains five dots, has within it a "p" (), a four-dot character, and an "m" (), an "f" (), and an "ff" (), which are three-dot characters. Parenthetically, all of these characters, except for "ff," were frequently confused with "q." Thus, if the reader is unsure of the braille stimulus, he has a greater probability of being correct by naming one of these three-dot characters than a character of more dots. This would, of course, explain the predominance of missed dot errors among the error types.

Another way of looking at this situation is that among the three-, four-, and five-dot characters there is a lack of distinctiveness of shape, and this dearth contributes to confusion among the characters. Apparently, this is what the UTC (1915, p. 20) had in mind when they said errors were caused by the "The general similarity of shape and position . . . " among some of the characters.

The tendency, noted in the results, to attend to the upper and left-hand portion of the braille cell and the inferior legibility of the lower cell characters were, no doubt, related, and derived from a number of factors. Among them are (*1*) certain aspects of tactual perception, (*2*) the directional quality of reading braille, wherein the left-hand column of dots is temporally sensed prior to the right-hand column, and (*3*) certain probability features of braille as it is used to represent written English.

In terms of influence, the most important factor was quite likely the latter, the probability features of braille. Kederis *et al.* (1965) conducted a frequency count of the elements of the braille code used in the reading material of the blind. They also counted the total number of occurrences of the 63 braille characters and of the six braille dots by position within the cell. The dot count showed that 70 percent of the characters were composed of three and fewer dots, and that the average number of dots in all of the characters of the sample was 2.88. Another finding from the dot count was a disproportionate occurrence of dots in the six positions of the braille cell. The total number of dots on the left-hand side of the cell was 30 percent greater than the total of the dots on the right. The total for the two top dots was 29 percent greater than the total for the bottom dots, and the total for the number 1 dot was 92 percent greater than the total for the number 6 dot. Using this character count, the present authors calculated rank order correlations between frequency of occurrence of characters in print and the order of legibility of the characters in this and two subsequent studies. Significant coefficients up to .46 in size were obtained. Thus, some of the characters' relative legibility was positively related to the greater frequency of occurrence of these elements in braille reading material.

One question raised by the results concerned the lack of relationship between character recognition thresholds and grade level of the subjects. Reading surveys by Niday (1939), Athearn, Campbell, and Lavos (1944), and the present investigators (unpublished) showed that reading achievement increased with advance in grade level. Increase in reading efficiency would logically be expected to be accompanied by an increase in efficiency of character recognition. Such was not the case in the present study. Absence of this effect is quite possibly due to the methods by which the subjects were selected and the small number of subjects included at each grade level.

This explanation would probably also account for the significant relationship between sex and recognition thresholds. This is all the more likely since analysis of the characters on which the sexes differed revealed no unique trends for either sex.

In summary, the legibility of the braille characters was found to be influenced by a number of properties of the individual characters. These properties were number and configuration of dots, distance between dots, and location of dots within the cell. In turn, the probability of occurrence of the characters and the dots appeared to be positively related to the effects of the properties.

These findings appear to have serious implications for the recognition of braille words. Some of these implications are explored in the several studies of word recognition described in the succeeding chapters.

SEVEN

Study II: The Effects of Word Length, Familiarity, and Orthography on Recognition Thresholds for Braille Words

IN STUDY I it was found that legibility was closely related to the number of dots in characters as well as to their configuration. If this finding transferred to the active reading situation, it could imply that point reading may occur in a manner quite different from that of print reading. In order to explore the problem further and to delineate some of the variables and difficulties that might be encountered, a pilot study was designed to determine the effect of word length, familiarity, and orthography on the recognition thresholds of braille words (Nolan and Kederis, 1963). The results of this pilot study were of such heuristic interest that the more intensive study described in this chapter was undertaken.

The objectives of the study were

1. To compare groups of fast and slow braille readers for differences in recognition thresholds for braille words of varying characteristics
2. To determine the effects of differences in length, familiarity, and orthography upon the recognition thresholds for braille words.
3. To compare the recognition times for braille words with the sum of the recognition times for the characters of which the words were composed.

Subjects

The 30 subjects in the experiment were legally blind readers from grades 9 through 12 of the Indiana, Ohio, and Tennessee schools for the blind. All students were given the Gates Basic Reading Test, Type A, Form 1 (braille edition) and ranked in order of reading speed scores. Subjects were then randomly selected from the upper third and lower third of this distribution. However, no subject in either group was selected who made a comprehension score below 20 out of a possible score of 24. This resulted in two reading groups—fast and slow. Data describing the subjects participating in the study can be found in Table 10.

TABLE 10 Subject Data

		Reading[a] *Time (min.)*	*Comp. Score*	*IQ*[b]	*Age (yrs.)*	*Grade*	*Sex* M	F
Fast readers	M	17.80	23.67	120.67	17.15	10.80	6	9
	SD	2.65	.62	12.69	1.27	1.21		
Slow readers	M	38.37	22.40	101.31	17.69	10.20	9	6
	SD	4.62	1.76	14.69	1.34	1.15		

[a] To obtain wpm reading rates for this and subsequent studies, divide the reading times into 2,100, the approximate number of words in each form of the Gates tests Type A.

[b] The numbers of fast and slow readers for these means are 12 and 13 respectively.

Method

DESIGN The study employed a 2 × 2 × 3 factorial design in which all treatments or conditions of the experiment were administered to each subject. The subjects were divided into two reading rate groups (R)—that is, fast and slow braille readers. The experimental conditions or treatments were as follows: (*1*) word length (L) which was varied to include words composed of 3, 5, and 7 braille characters; (*2*) familiarity (F) which was varied between familiar and unfamiliar words; and (*3*) orthography (O) which was varied to include both fully spelled and contracted braille words.

MATERIALS Familiarity was based on the frequency of appearance of words in English print as determined by Thorndike. Familiar words came from the most frequent 5,000 words, while unfamiliar words were selected from the categories above the most frequent 10,000 words. No attempt was made to control the types, positions, or numbers of contractions in the contracted words. Three words were selected to represent each treatment combination resulting in a total of 36. A list of the words used appears in Appendix A.

Using a table of random numbers, five different sets of random orders for the 36 words were developed. The words in each random order were embossed on a separate sheet of paper with nine lines to a page and four words to a line. A full braille cell, or "for" sign, was embossed in the first space immediately preceding each word. The appearance of the "for" sign served as the cue for the subject to begin reading upon each symbol exposure. It also served to make the process more realistic from the standpoint of touch reading movements.

Thirty-two single-cell braille characters which were among those included in the words were also placed in five different random orders and embossed on two sheets of paper. Each page consisted of 10 lines with 8 characters to the line. A "for" sign was embossed in the first space immediately preceding each braille character.

APPARATUS The tachistotactometer, described in Study I, was used to present tactual stimuli in braille form under time conditions.

PROCEDURE The complete experiment required approximately five one-hour sessions for each subject—one in which the standard group reading test was administered and four in which the recognition threshold values were obtained. The reading test was administered approximately one month prior to the recognition study.

During the word recognition phase each hour-long session for each subject took place in the same room at varying times of the day for four consecutive days. The different times were necessary in order to minimize interference with the subjects' class schedules. On the first day the subjects were instructed in the task and given sufficient practice on similar materials to acquaint them with the apparatus and the procedure. Following practice the determination of thresholds was begun.

The recognition threshold values for both the words and letters were obtained using the method of minimal changes as described in Study I. Each of the 36 words in the first random order was presented to the subject at the same below-threshold exposure time by means of the tachistotactometer. After each presentation the subject's verbal response to the stimulus was recorded. As soon as all words in a random order were presented, the exposure time was increased .10 sec and another random order presented. When a word was correctly identified it was excluded from further presentations. Sequence of presentation was random orders 1, 2, 3, 4, 5; 1, 2. . . . This procedure was followed until all of the words had been correctly identified which required approximately three sessions. During this procedure a record was made of the earliest time at which at least one reading finger of the subject traveled over all characters in a word. This time was called the "cover time."

In a similar manner recognition threshold values were determined for the 32 single cell characters. However, in this case, the criterion for recognition was two correct identifications out of three successive exposures. The increase in exposure times between random orders of characters was .01 sec. Identification of all the characters required about one session.

Results

The following analyses of the results have been made. First, the means of the several combinations of treatments or conditions of the experiment have been tested for significant differences among them. Next, tests have been made to determine if the characters studied differed in time required for recognition and if fast and slow readers differed in the time they required to recognize braille characters. The average times required to recognize words fitting the various combinations of conditions of the experiment were then compared with the average times required for at least one reading finger to encounter all the characters in the words (cover time). These in turn were compared with the sums of the recognition times for the characters included in the words (synthetic recognition time). The next analysis for words involved comparison of the ratios of recognition times to the cover times for fast and slow readers under certain combinations of conditions in the study. The last word analysis compared fast and slow readers for ability to recognize words before at least one reading finger had touched all characters.

Further analysis of the character recognition data follow. A comparison was made of the mean recognition times for fast and slow readers when characters were grouped according to the number of dots in the character. Finally, the missed dot errors of fast and slow readers were compared when they were classified according to the dot position of the omitted dot.

Table 11 presents the means and standard deviations for the word recognition times under each combination of treatments in the study for the groups of fast and slow readers. In computing these means, the cell entry for each subject was his mean score on the three words representing a given treatment combination.

TABLE 11 Means and Standard Deviations of Each Treatment for Fast and Slow Readers

		Familiar						*Unfamiliar*					
		Uncontracted			Contracted			Uncontracted			Contracted		
		3	5	7	3	5	7	3	5	7	3	5	7
Fast readers	M	.53	.63	.75	.54	.56	.70	.74	.88	.94	.78	.99	1.02
	SD	.10	.14	.19	.12	.13	.21	.15	.15	.19	.18	.15	.21
Slow readers	M	.82	1.11	1.31	.87	1.00	1.32	1.19	1.53	1.71	1.30	1.77	1.90
	SD	.38	.42	.36	.41	.38	.45	.35	.42	.42	.37	.48	.48

Table 12 reports the results of a test for significance of differences among these means using analysis of variance techniques as described by Winer (1962, Chap. 7). The results of this analysis indicate that the mean recognition thresholds for braille words increase significantly as words become longer, less familiar, and include braille contractions. The effects of these factors are dynamically interrelated as indicated by the significant interactions—that is familiarity and length (F × L), familiarity and orthography (F × O), and familiarity, length, and orthography (F × L × O). The meaning of interaction is that change along the dimensions of one experimental variable produces effects that are unequal along the dimensions of a second experimental variable. For example, the effect of the increase in number of characters on difficulty of word recognition is much more severe for unfamiliar words than for familiar words. However, a reverse effect occurs in the case of the F × O interaction. In this case shift in words along the ortho-

TABLE 12 Results of the Analysis of Differences in Recognition Thresholds for Braille Words Categorized According to Familiarity (F), Length (L), and Orthography (O) When Presented to Groups (R) of Fast and Slow Readers

Source of Variation	*SS*	*df*	*MS*	*F*
Between subjects	*57.34*	*29*		
R (reading rate)	28.61	1	28.610	27.88[a]
Subj. w. groups	28.73	28	1.026	
Within subjects	*32.38*	*330*		
F (familiarity)	13.36	1	13.360	151.82[a]
F × R	1.12	1	1.120	12.73[a]
F × Subj. w. groups	2.46	28	.088	
L (length)	7.92	2	3.960	165.00[a]
L × R	1.48	2	.740	30.83[a]
L × Subj. w. groups	1.35	56	.024	
O (orthography)	.24	1	.240	20.00[a]
O × R	.08	1	.080	6.67[b]
O × Subj. w. groups	.35	28	.012	
F × L	.37	2	.185	9.74[a]
F × L × R	.03	2	.015	.79
F × L × Subj. w. groups	1.05	56	.019	
F × O	.53	1	.530	35.33[a]
F × O × R	.05	1	.050	3.33
F × O × Subj. w. groups	.41	28	.015	
L × O	.00	2	.000	.00
L × O × R	.01	2	.005	.36
L × O × Subj. w. groups	.78	56	.014	
F × L × O	.19	2	.095	8.64[a]
F × L × O × R	.01	2	.005	.45
F × L × O × Subj. w. groups	.59	56	.011	
Total	89.72	359		

[a] $p \leq .01$
[b] $p \leq .05$

graphic dimension from uncontracted to contracted serves to decrease the recognition thresholds for familiar words but to increase the recognition thresholds for unfamiliar words.

A significant difference in mean recognition thresholds for fast and slow braille readers was found. All first-order interactions between the various individual treatments and the rate of reading ability were found to be significant.

The average recognition thresholds for 32 of the braille characters included in the words of the study are given in Table 13. Separate mean thresholds are given for the fast and slow reading groups. Also given are the group medians and ranges for all characters. It is interesting to note not only that the group medians differ by a considerable margin, but also that the group threshold distributions overlap on only one score category with a frequency of 1 each.

Also appearing in Table 13 is the product-moment correlation of the character recognition times for the groups of fast and slow readers. This coefficient is .80 and is significant from zero beyond the .01 level of confidence.

TABLE 13 Mean Recognition Thresholds for 32 Braille Characters for Groups of Fast and Slow Readers

	Reading Group Mean (sec)			*Reading Group Mean (sec)*	
Character	Fast	Slow	Character	Fast	Slow
a	.08	.16	s	.07	.15
b	.10	.15	t	.11	.19
c	.06	.14	u	.09	.16
d	.09	.15	v	.09	.18
e	.07	.13	w	.09	.20
f	.09	.17	y	.11	.17
g	.09	.17	th	.08	.16
i	.07	.15	ar	.09	.17
j	.10	.18	ble	.10	.19
k	.08	.15	ou	.11	.22
l	.07	.17	st	.07	.16
m	.06	.15	in	.10	.19
n	.09	.15	ch	.08	.16
o	.07	.14	er	.10	.22
q	.13	.23	en	.11	.19
r	.11	.21	and	.12	.20

Median for all characters: .09; .17
Group range: .06–13; .13–23
Correlation between recognition times of fast and slow readers: $r = .80$ (sig. $p < .01$ level of confidence)

The analysis of the mean recognition times for characters described in Table 14 indicates these differences between reading levels are significant at far beyond the .01 level of confidence. Differences in recognition thresholds for characters are also highly significant. The character × reading rate interaction is not significant.

TABLE 14 Analysis for Differences Among Recognition Times of 32 Braille Characters

Source	*SS*	*DF*	*MS*	*F*
Between subjects	*3.61*	*29*		
R (reading rate)	1.62	1	1.62	23.14[a]
Error	1.99	28	.07	
Within subjects	*1.82*	*930*		
C (characters)	.39	31	.013	6.50[a]
C × R	.04	31	.001	.50
Error w	1.39	868	.002	
Total	5.43	959		

[a] $p \leq .001$

Three sets of data related to the recognizability of braille words when classified by the various treatment combinations and levels can be found in Table 15. One set gives again the mean recognition thresholds for both fast and slow readers. A second set gives the mean "cover time" for each treatment combination × reading rate group. The cover time was defined as the minimum time for at least one reading finger of the reader to travel over all the characters of a word. The last set of data represents synthetic recognition times for the words. For any word, the synthetic recognition time is the sum of the mean recognition thresholds for the characters included. Such means were determined separately for each reading group.

In order to complete data collection within one week, it was not possible to include all the characters used in the stimulus words. Therefore, the synthetic recognition times for some categories of seven character words are based upon estimates derived from only one or two words.

The increase in recognition times as braille words become longer,

TABLE 15 Mean Recognition Times, Cover Times, and Synthetic Recognition Times of Groups of Fast and Slow Braille Readers for Braille Words Categorized by *F*amiliarity-*Unf*amiliarity, *Unc*ontracted-*C*ontracted, and Word Length

	Mean Recognition Time (sec)		*Mean Cover Time (sec)*		*Synthetic Recognition Time (sec)*	
Readers	Fast	Slow	Fast	Slow	Fast	Slow
Word Type			*3-character words*			
FUnc	.53	.82	.42	.63	.24	.48
FC	.54	.86	.43	.68	.26	.48
UnfUnc	.74	1.19	.41	.60	.25	.49
UnfC	.78	1.30	.44	.73	.28	.55
			5-character words			
FUnc	.63	1.11	.55	.91	.42	.79
FC	.56	1.00	.53	.95	.42	.86
UnfUnc	.88	1.53	.59	.93	.39	.77
UnfC	.99	1.77	.62	1.04	.46	.87
			7-character words			
FUnc	.74	1.31	.68	1.09	.57	1.12
FC	.70	1.32	.74	1.30	.57	1.14
UnfUnc	.94	1.71	.75	1.19	.55	1.12
UnfC	1.02	1.90	.81	1.35	.58	1.12

less familiar, and change from uncontracted to contracted has already been mentioned, and these effects are apparent among the data in Table 15. The mean cover times reported appear most closely related to word length and, for any given word length, vary to a much lesser extent than do the recognition times. All cover times save one for seven-character words are of shorter duration than their associated recognition times. Recognition of seven-character words by some subjects prior to covering all the characters was responsible for this exception.

The synthetic recognition times listed in Table 15 are the shortest of all. They also appear closely related to word length and show the least variation within length categories.

Table 16 contains several sets of ratios of recognition times to cover times for braille words categorized by the treatments of the experiment and their combinations. Comparisons of these ratios are made for the groups of fast and slow readers. In Table 16c, comparisons for words of different length are given. For words of three characters, the recognition time is more than 50 percent greater than the time required for the reading digit to cover the characters, and as words increase in length the disparity between these two measures decreases. These effects appear to be similar for both fast and slow braille readers, as is the case for all additional sets of data to be discussed below.

Ratios of recognition to cover times grouped by word familiarity appear in Table 16a. The effect of unfamiliarity is to increase the degree to which the recognition times exceed the cover times.

Table 16b compares these ratios when words are grouped by orthography. Ratios for contracted braille words appear to be slightly smaller than those for uncontracted words.

The effects of the interaction of word length and familiarity on the recognition to cover time ratio can be observed in Table 16e; the effects of the interaction of word length and orthography are given in Table 16f; and the effects of the interaction of familiarity and orthography appear in Table 16d.

The requirement of the study that 30 subjects each recognize 36

TABLE 16 Comparison of Ratios of Mean Recognition Times to Mean Cover Times for Groups of Fast and Slow Braille Readers for Words Categorized by the Treatments and Their Combinations

(a) By Familiarity

	Fast Readers	*Slow Readers*
Fam.	1.10	1.15
Unfam.	1.47	1.61

(b) By Orthography

	Fast Readers	*Slow Readers*
Uncontracted	1.32	1.43
Contracted	1.28	1.35

(c) By Length

	Fast Readers	*Slow Readers*
3	1.52	1.59
5	1.33	1.41
7	1.14	1.26

(d) By Familiarity and Orthography

	Fast Readers	*Slow Readers*
Fam.-uncon.	1.15	1.23
Fam.-con.	1.06	1.09
Unfam.-uncon.	1.47	1.64
Unfam.-con.	1.49	1.59

(e) By Length and Familiarity

	Fast Readers	*Slow Readers*
3 fam.	1.26	1.28
3 unfam.	1.78	1.89
5 fam.	1.10	1.14
5 unfam.	1.54	1.67
7 fam.	1.01	1.10
7 unfam.	1.25	1.43

(f) By Length and Orthography

	Fast Readers	*Slow Readers*
3 uncontracted	1.54	1.64
3 contracted	1.52	1.54
5 uncontracted	1.33	1.43
5 contracted	1.35	1.39
7 uncontracted	1.18	1.33
7 contracted	1.11	1.22

words resulted in a total occurrence of 1,080 word recognitions. It should be recalled that the words consisted of 12 sets of three words each corresponding to possible combinations of the treatment variables familiarity, word length and orthography. In 111, or 10 percent, of these 1,080 occurrences, words were recognized before the reading fingers of the subject had covered all the characters in the word. Data describing the frequency of occurrences of this kind are presented in Table 17.

TABLE 17 Number of Words Correctly Recognized Before All of the Characters Were Touched

	Fast Readers				*Slow Readers*				
	Familiar		Unfamiliar		Familiar		Unfamiliar		
	Unc	Con	Unc	Con	Unc	Con	Unc	Con	
Length									
3	1	—	—	—	2	—	—	—	3
5	11	15	—	—	9	10	—	—	45
7	12	20	1	1	13	15	1	—	63
Total	24	35	1	1	24	25	1	—	111

It can be seen from Table 17 that without sensing all the characters the fast readers recognized about 20 percent more of the contracted words than did slow readers. However, beyond this point the reading groups do not appear to differ. Very few three-character words or unfamiliar words of any length were recognized in this manner. As braille words became longer, the frequency of recognition based on partial sensing increased.

Table 18 gives the mean recognition times of braille characters for both fast and slow readers when characters are grouped according to the number of dots included in each. These data do not appear to differ other than on the basis of the differences demonstrated between the groups of fast and slow readers in Table 13.

TABLE 18 Mean Recognition Times for Braille Characters for Fast and Slow Readers According to the Number of Dots in Each Character

	Fast Readers					*Slow Readers*				
	Dots					Dots				
	1	2	3	4	5	1	2	3	4	5
	.08	.10	.09	.09	.13	.16	.15	.15	.17	.23
		.06	.09	.09	.11		.14	.17	.15	.17
		.07	.10	.11	.10		.13	.18	.21	.22
		.07	.07	.11	.12		.15	.17	.19	.20
		.08	.06	.09			.15	.15	.18	
		.07	.07	.09			.16	.14	.20	
		.10	.07	.08			.19	.15	.16	
		.08	.09	.10			.16	.16	.19	
		.11	.09	.11			.19	.17	.22	
Total mean	.08	.08	.08	.10	.12	.16	.16	.16	.19	.20

A number of analyses of types of errors were made in order to identify classes of errors and compare the reading groups for these classes. The errors made include missed dots, added dots, reversals, horizontal alignment, and vertical alignment. No great differences among reading groups in types of errors were found.

When missed dot errors are analyzed according to their position within the braille cell, it appears that these increase in frequency as dot position shifts from left to right in the cell and from top to bottom in the cell. This phenomenon appears to occur with greater frequency for slow readers than for fast readers. Table 19 gives the frequency of missed dot errors for both reading groups, when such errors are classified by braille cell position. Data in Table 19 are based upon analysis of only those erroneous responses which were given by at least 25 percent of all subjects in the experiment.

TABLE 19 Proportions of Missed Dot Errors Classified by Dot Position Within the Braille Cells Using Errors Common to at Least 25 Percent of the Readers

Dot Positions	*Proportions of Missed Dots* Fast Readers	*Proportions of Missed Dots* Slow Readers
1	.04	.05
2	.12	.13
3	.14	.14
4	.18	.19
5	.23	.21
6	.29	.27

Discussion

The significant differences found for the treatments (familiarity, length, and orthography) in the study and for their interactions in all likelihood provide only a hint of the complexity of the braille reading process. As might be expected, slow braille readers are characterized by recognition thresholds that are significantly greater than those which typify fast braille readers. In addition, the significant interactions between the individual treatments and reading rate groups indicated that changes in the complexity of the treatment variables have greater consequences for slow readers than fast.

One factor that does not appear to be involved in differences in character recognition among fast and slow braille readers is character configuration or form. The agreement in order of character legibility between the two groups was quite high ($r = .80$) as was reported in Table 13.

Recognition thresholds for both good and poor readers appear to bear some relationship to the number of dots in the characters as previously found in Study I.

In the Preface it is mentioned that in visual reading familiar words of varying length are recognized at exposure times shorter than or equivalent to those for individual letters. Comparison of similar data for braille reading illustrates the vast difference in the dynamics of the print and braille reading processes. For fast braille readers recognition times for characters in no case exceed .13 sec (Table 13). Furthermore, the recognition times for the shortest familiar braille words exceeded this maximum by more than a factor of four (Table 11). The case for slow braille readers is analogous. Recognition of braille words is far slower process than recognition of individual braille characters which is exactly opposite to the behavior of sighted readers.

It is interesting to note (Table 15) the great differences between the times required to recognize braille words and the sums of the recognition thresholds for the characters included in the words. Termed synthetic recognition thresholds, these quantities are by definition very directly related to word length. They can be estimated by multiplying the number of characters in a word by a factor of .08 sec for fast readers and a factor of .18 sec for slow readers. The implication of the differences between the recognition thresholds and synthetic recognition thresholds for braille words, at least under the conditions of the experiment, is that the task of identifying a word takes from 50 to 150 percent more time than identification of the characters included. It is believed that this time is spent integrating the information derived from recognition of the individual characters. Some of this integration very probably occurs during the movement from character to character within a word. The times for at least one reading finger of the subject to more over the characters of the word (cover time) exceed the synthetic recognition times by about 30 to 50 percent. The time of actual movement of the reading fingers may be responsible for part of this difference. However, the recognition thresholds for the individual braille characters include the times required for the reading finger to move from a "for" sign immediately preceding each character Therefore, since movement times are included in the synthetic recognition thresholds the differences between these and the cover times appear predominantly due to the integration function.

The familiarity of a word does seem to contribute to a reduction of the integration portion of its recognition time. The differences among the recognition thresholds and the cover times or synthetic recognition times are much greater for unfamiliar words than for familiar words.

The comparisons of the ratios of mean recognition times to mean cover times for both groups of readers (Table 16) reveal many interesting aspects of the braille reading process. These ratios for slow readers are uniformly higher than those for fast readers. Not only do these groups differ in character recognition skills, but the integrative aspect of the reading process is proportionately greater for slower readers. This finding increases the possibility that differences in reading ability between these groups may be related to intellectual differences.

When braille words are categorized according to length (Table 16c), it is interesting to note that recognition times begin to approach cover times as word length increases. For longer words, the accumulation and integration of information as the characters are covered allows for recognition before, at the time of, or soon after encounter with the last character. This finding is in keeping with other findings in the field of communication and information theory. However, this result may be due, in part, to the structure of the language itself.

Table 16a emphasizes the effects of familiarity upon diminishing differences among the reading measures as discussed above. Familiar words are recognized much sooner after all characters are encountered than is unfamiliar words. The interaction of word length and familiarity are shown by the data in Table 16e. The effects of this interaction appear to be more beneficial to fast readers than to slow.

Contractions in braille words appear to reduce the relative time spent by both groups in the integrative aspects of reading (Table 16b). This increase in efficiency of reading for contracted words no doubt is derived from the fact that contracted braille words average more information per braille character. Such effects are extremely marked in the case of familiar words (Table 16d), while little or no such effect is evident for unfamiliar words. These same effects appear to be somewhat greater for longer words than for shorter words (Table 16f).

The importance of the role of familiarity in the recognition of braille words is emphasized by the findings that some words are recognized before all characters are covered by the reading fingers. This almost never occurred in the case of unfamiliar words and then only for three words of seven characters. For familiar three-character words this phenomenon is quite infrequent. Its frequency increases dramatically for words of five and seven characters and thus appears positively related to the number of characters in the words. Fast readers excel slow readers in frequency of such occurrences by a factor of 20 percent. Word structure no doubt plays a great part in the occurrence of this phenomenon. Inspection of the words used in the study (Appendix A) reveals the stems and beginnings of many words contain a substantial amount of the information required to recognize the whole. This effect would, of course, be directly related to word length.

Of considerable interest was the finding that fast and slow readers do not differ greatly in the types of errors they make. The error types found for subjects in the study were those characterizing braille readers generally and have been carefully analyzed and described by Ashcroft (1960). The relationship between frequency of missed dot errors and dot position within the braille cell was of particular interest. The reason why errors of this type increase as dot position changes from top to bottom and left to right in the cell is not apparent in the data. The over-all reading orientation of the subject may be involved, with tops of braille words playing the greater role in their perception. Expectancies, based on past experience, of the probability of the occurrence of braille dots in the various cell positions may be responsible for the varying error frequencies.

It should be noted that the process for word recognition used in this study departed from that common to most reading situations. Also the group of words studied was small. In spite of these shortcomings, the results of the study are revealing and suggest the directions for a variety of studies of perception in word recognition. The studies that follow are based on these suggestions and attempt to identify additional characteristics of braille words that are related to their perception.

EIGHT

Study III: Influence of Number of Dots and Position of Dots on Recognition Thresholds for Braille Words

IN THE previous study of braille word recognition (Study II), it was found that familiarity, word length, the presence or absence of contractions, and the subjects' level of reading ability produced significant variation in the recognition thresholds of words. An examination of errors in responses to words and to individual characters (studies I and II) revealed that the dots in the upper part of the braille cell were perceived more frequently than those in the lower part. Moreover, a comparison of recognition times for words and characters by fast and slow readers indicated slow reading was characterized by slow character recognition. In Study I, it was found that recognition times for braille characters were greatly affected by the number of dots included.

The purpose of this study was to explore several of the questions raised by the findings mentioned above. These questions were

1. Does the number of dots in a braille word influence its recognition time?
2. Are words with a preponderance of dots in the upper parts of their braille cells identified more quickly than words with approximately an equal number of dots in both the upper and lower parts of their cells?
3. What is the influence of contractions on recognition times for braille words as number and position of dots within words vary?

4. Do groups of fast and slow braille readers differ significantly in IQ or tactual sensitivity?

Subjects

The 30 subjects consisted of 15 fast and 15 slow braille readers from grades 9 through 12 at the Indiana, Ohio, and Tennessee state schools for the blind. Reading ability was determined by reading time and comprehension scores on Form 1 of the Gates Basic Reading Test, Type A (braille edition). The subjects were randomly selected from the upper and lower thirds of the distribution of 87 high school braille readers. Only subjects with a comprehension score of 20 or greater were considered. A pool of alternates was chosen at the time of the original selection. Because some of the reading test scores were approximately a year old, the selected subjects were retested immediately prior to their participation. If their reading performance had changed during the course of the year, they were replaced by one of the alternates. All subjects so selected were then given the Roughness Discrimination Test following the directions described in the Manual. Subject data are presented in Table 20.

TABLE 20 Subject Data

		Reading Time (min)	*Comp. Scores*	*IQ*[a] *Scores*	*Roughness*[b] *Disc. Scores*	*Age (yr)*	*Grade*	*Sex* M	F
Fast	M	19.80	23.20	120.07	59.73	16.10	9.70	7	8
read.	SD	3.64	1.08	21.56	5.28	1.64	.82		
Slow	M	34.30	22.90	102.73	58.33	17.49	9.90	6	9
read.	SD	6.63	1.16	15.94	5.07	2.41	1.01		

[a] Results of *t*-test indicated IQ scores of fast and slow readers differed significantly at the .02 level of confidence.

[b] Test of mean differences of roughness discrimination scores between fast and slow readers was not significant

Method

DESIGN A 5 × 2 × 2 × 2 factorial design with all treatments administered to each subject was used. Subjects were divided into two reading rate groups (R)—fast readers and slow readers. The treatments consisted of number of dots in a word (ND)—varied through five steps of two dots each from 11 to 19; position of dots in a word (P)—varied between words with a preponderance of dots in the upper part of the word and words with dots evenly distributed throughout the word; and orthography (O)—varied between words with contractions and words without contractions. Familiarity of words was equated among treatments using data derived from Thorndike (1932) with only words within the most frequent 5,000 included. All words were comprised of five braille characters. Two words were studied for each treatment combination making a total of 40 words. In order to eliminate cues emanating from word length 16 extra words of three and seven characters were also included. A list of the words used in the study appears in Appendix B.

MATERIALS The 65 stimulus and extra words were arranged in three random orders. These random orders were embossed consecutively on four sheets of special plasticized paper to insure high relief for the braille dots. The first three sheets contained 12 lines of four words each and the final sheet contained six lines of four words each.

APPARATUS The Roughness Discrimination Test used to measure tactual ability was developed for use as a predictor of readiness of first grade children to learn to read braille (Nolan and Morris, 1965). The test was composed of 69 items, each of which consisted of a 3.5 × 12.5 inch card upon which were mounted four pieces of sandpaper two inches square. Three of the squares were of equal grit size while the fourth was of a larger grit size. The task for the subject was to feel each of the four squares and identify the one that was different from the other three.

The device used to establish recognition thresholds for words was the tachistotactometer described in Study I.

PROCEDURE The complete experiment required two half-hour sessions and three one-hour sessions for each subject. The sessions were held in the same room and at different times each day. The variable times were necessary in order to minimize interference with each subject's class schedule.

The two half-hour sessions were held on the first day. In the morning the group of children who had been selected at each participating school was given the Gates reading test. The test was used in accordance with the directions given for use with the blind. In the afternoon the Roughness Discrimination Test was individually administered according to the instructions established by the authors.

Collection of data on recognition times was begun on the second day. In this phase the subjects participated individually for an hour on each of three consecutive days. The procedure for establishing recognition thresholds was the same as previously described for Study II.

Results

Table 20 presents means and standard deviations for IQ scores and Roughness Discrimination Test scores for the groups of fast and slow readers. The groups differ by 18 points in intelligence (significant at the .02 level of confidence). However, no significant differences in tactual sensitivity were apparent.

The mean recognition times for words classified according to the various treatment and level combinations in the study are given in Table 21. Inspection of this table does not reveal any strong trends

TABLE 21 Mean Recognition Times[a] for Words Classified According to Treatments and Reading Groups

Orthography	*Dot Distribution*	*Number of Dots* 11	13	15	17	19	*Group Means*
		Fast Readers					
Uncontracted	upper cell	.80	.83	.80	.98	.69	.82
	entire cell	.96	.75	.77	.81	.84	.83
Contracted	upper cell	.75	.80	.77	.80	.82	.79
	entire cell	.85	.77	.87	.82	.81	.82
		Slow Readers					
Uncontracted	upper cell	1.22	1.24	1.26	1.36	1.16	1.25
	entire cell	1.47	1.25	1.32	1.27	1.20	1.30
Contracted	upper cell	1.22	1.26	1.23	1.35	1.31	1.27
	entire cell	1.35	1.32	1.34	1.33	1.31	1.33
Group Means		1.08	1.03	1.04	1.09	1.02	

[a] Times are in seconds

related to the conditions of the experiment other than the obvious differences in recognition times between groups of fast and slow readers.

Table 22 presents data describing the outcome of analysis of these means for possible significant differences among treatments and reading groups. The analysis of variance methods used are those described by Winer (1962) for repeated measures.

TABLE 22 Analysis of Mean Recognition Times of Words Presented to Fast and Slow Readers (R), and Classified by Number of Dots (ND), Position of Dots (P), and Orthography (O)

Source	*SS*	*DF*	*MS*	*F*
Betw. subjects	*99.0791*	*29*		
R	33.7962	1	33.7962	14.50[a]
Subj. w. grps.	65.2829	28	2.3315	
Within subjects	*12.8103*	*570*		
ND	.4589	4	.1147	5.24[a]
ND × R	.0168	4	.0042	.19
ND × S	2.4583	112	.0219	
P	.2242	1	.2242	13.03[a]
P × R	.0385	1	.0385	2.24
P × S	.4816	28	.0172	
O	.0042	1	.0042	.27
O × R	.0684	1	.0684	4.47[b]
O × S	.4282	28	.0153	
ND × P	.8558	4	.2140	9.55[a]
ND × P × R	.0910	4	.0228	1.02
ND × P × S	2.5077	112	.0224	
ND × O	.4545	4	.1136	4.67[a]
ND × O × R	.0959	4	.0240	.99
ND × O × S	2.7226	112	.0243	
P × O	.0097	1	.0097	.69
P × O × R	.0079	1	.0079	.56
P × O × S	.3946	28	.0141	
ND × P × O	.3421	4	.0855	8.81[a]
ND × P × O × R	.0606	4	.0152	1.57
ND × P × O × S	1.0888	112	.0097	
Total	111.8894	599		

[a] $p \leq .01$

[b] $p \leq .05$

For the treatments, differences significant beyond the .01 level of confidence exist for number of dots and position of dots within a word. Orthographic differences (contractions or no contractions) between words did not create significant differences in recognition thresholds under these conditions. As expected, fast readers had significantly lower thresholds than did slow readers.

When the interactions of the individual treatments with the levels of the experiment are examined, it is found that only the orthography with reading rate groups (O × R) interaction is statistically significant (.05 level of confidence).

Of the first order interactions among treatments, two are significant at the .01 level of confidence. These are the number of dots with position of dots (ND × P) and number of dots with orthography (ND × O) interactions. The position with orthography (P × O) interaction falls far short of statistical significance. The second order interaction ND × P × O is significant at the .01 level of confidence. However, the third order interaction (ND × P × O × R) fails to reach significance.

Discussion

In Study II it was again found that fast and slow readers differed greatly in ability to recognize individual braille characters. Several factors were suggested as sources of these differences including intelligence and tactual ability. Results of the present study indicate intellectual differences may be a more significant factor than tactual ability. However, the adequacy of the measure of tactual ability for use with the subjects of this study may be questioned. Inspection of the data in Table 20 shows that scores of both groups of readers clustered near the upper end of the roughness test score continuum. Therefore, it appears that the level of difficulty of the test may have been too low to discriminate real differences in tactual ability existing between these groups.

The results of this study tend to reinforce and extend the findings of the previous studies. Not only does number of dots appear relevant to the recognition of braille characters (Study I), but also to the recognition of braille words. However, the way in which the number of dots in a word affects word recognition is not clear. Inspection of the means for the dot categories in Table 21 does not reveal systematic variation in word recognition thresholds as the number of dots in words changes. Uncontrolled factors among words representing the dot number categories may be responsible for the unsystematic variation of these means.

The effects of number of dots upon the word recognition thresholds in the study are contingent upon the orthography of words and the degree of distribution of the dots throughout words as indicated by the statistically significant interaction between these variables. However, no clearcut relationships are evident.

One source of this confusion may be inadequate control of the difficulty of the stimulus words. For example, the words "glory" and "funny" which were among those containing the most dots, were the easiest of all words to recognize. Why this should be the case is not readily apparent. The word "mamma" also appeared to represent a special case. Difficulty of this word greatly exceeded those of other words within its classifications. It was later learned that this word is commonly spelled "mama" in present-day school texts. This difference in spelling may account for the high level of difficulty students experienced in recognition of this word. A different problem existed in the case of the word "Negro." The two Negro children in the study exhibited blocking on this particular word. In view of these problems, further study of the effects of number of dots under conditions of more adequate control seems desirable.

Additional evidence of the directionality of integration of information in braille reading was obtained. Obviously, by the very nature of the task this must be from left to right. However, findings of Study I indicated that for braille characters integration may occur simultaneously in left to right and top to bottom directions. Significant differences among recognition times for braille words which differ in the distribution of dots within the word indicate that integration of information within words also proceeds from top to bottom.

The previous finding in Study II that orthography is a significant factor in the difficulty of recognition of braille words does not appear to be substantiated in this study. However, examination of the significant R × O interaction (see Table 21) reveals a differential effect of this variable. For fast readers of familiar words inclusion of contractions reduces recognition times. Some evidence for this phenomena can be seen also among the data of Study II.

In summary, this study identifies additional dimensions of braille words that affect their ease of recognition. These include the number of dots in words, the position of dots within words and their orthography. As was the case in previous studies, these factors interact in their effects on word recognition.

NINE

Study IV: Influence of Braille Contractions upon Recognition Thresholds for Words

IN STUDIES II and III it was found that thresholds for contracted braille words generally were significantly greater than those for uncontracted words. However, effects of contractions were such as to reduce thresholds for familiar words and increase thresholds for unfamiliar words. In Study III, with familiarity and word length held constant, contracted words were easier for fast readers than uncontracted words, while for slow braille readers the reverse was true.

The present study was designed to explore more thoroughly the effects of inclusion of contractions upon the recognition thresholds for braille words. The study attempted to answer the following questions:

1. Does the number of contractions in a word affect its recognition threshold?

2. Does the position of the contraction within the braille cell affect recognition thresholds?

3. Does the position contractions occupy within words affect their recognition thresholds?

4. How does the familiarity of words combine with number and position of contractions to affect their recognition thresholds?

Subjects

Twenty students were randomly selected from among 55 braille readers in grades 9 through 12 of the Michigan and Kansas state schools for the blind. Data describing the subjects may be found in Table 23.

TABLE 23 Subject Data

	Age (yrs)	*Grade*	*IQ*	*Sex* M	F
Mean	16.43	10.25	117.30	10	10
SD	1.36	1.12	14.30		

Method

DESIGN A 2 × 2 × 2 × 3 factorial design was used in which all subjects were administered each treatment. The treatments were defined as follows: number of contractions (N)—varied between one and two contractions per word; type of contractions (T)—varied between contractions containing dots in all three rows of the braille cell and contractions with dots falling only in the bottom two rows of the cell; position of contractions (P)—varied to include words with contractions falling in the initial, middle, and final part of the word; and familiarity (F)—varied between familiar and unfamiliar words.

Familiarity of words was determined from the Thorndike (1932) word list. Familiar words were selected from among those listed as the most frequent 5,000 and unfamiliar words were selected from among those listed as between the 15,000 and the 20,000 most frequent. Because the number of dots in a word appeared to affect its recognition threshold (Study III) only words containing between 13 and 15 dots were included. Since this same study had shown that position of dots within words was also critical, care was taken that stimulus words for the treatment categories did not differ widely in this respect. Only words of five braille characters were included among the stimulus words. However, to prevent response sets based on word length from arising, eight extra three-character words and eight extra seven-character words were included. Since two words were selected to represent each of the 24 treatment combinations, this resulted in a total of 64 words for presentation to the subjects. A list of these words can be found in Appendix C.

MATERIALS The 64 words were arranged in three different random orders. These were embossed on four sheets of especially plasticized paper to assure high relief of the braille dots. Each sheet contained 12 lines of words with four words falling within each line.

APPARATUS The apparatus used to establish recognition thresholds was the tachistotactometer described in Study I.

PROCEDURE The procedure followed was identical to that described for the previous studies. Three one-hour sessions on consecutive days were necessary to collect the data for this study.

Results

Table 24 gives the mean recognition times for the various treatments. Table 25 presents the results of analysis of differences among the mean recognition thresholds for the variables studied. Among these, differences significant at the .01 level of confidence existed for the classifications familiar-unfamiliar and number (one or two) of contractions. Type of contraction and the position of contractions within words were not generally significant variables in the recognition of the words used in this study.

Among the first-order interactions, familiarity with number of con-

TABLE 24 Mean Recognition Times for Words Classified According to Position of Contractions (Initial, Middle, Final), Number of Contractions (One, Two), and Type of Contractions (Whole Cell, Lower Cell)

	Familiar			*Unfamiliar*			
	I	M	F	I	M	F	Total
One							
Whole	.89	.84	.88	1.04	1.04	1.09	.96
Lower	.87	.88	.93	1.06	.99	1.03	.96
Two							
Whole	.88	.86	.98	1.10	1.11	1.14	1.01
Lower	.85	.83	.86	1.25	1.26	1.08	1.02
Total	.87	.85	.91	1.11	1.10	1.08	

TABLE 25 Results of Analysis of Differences Among Recognition Thresholds for Words Classified According to Familiarity (F), Number of Contractions (N), Type of Contractions (T), and Position of Contractions (P)

Source	*SS*	*DF*	*MS*	*F*
F	5.8080	1	5.8080	140.63[a]
F × S	.7843	19	.0413	
N	.3521	1	.3521	18.73[a]
N × S	.3572	19	.0188	
T	.0021	1	.0021	.11
T × S	.3618	19	.0190	
P	.0480	2	.0240	1.28
P × S	.7136	38	.0188	
F × N	.4201	1	.4201	28.58[a]
F × N × S	.2789	19	.0147	
F × T	.0608	1	.0608	5.96[b]
F × T × S	.1936	19	.0102	
F × P	.1547	2	.0774	5.86[a]
F × P × S	.5037	38	.0132	
N × T	.0041	1	.0041	.59
N × T × S	.1333	19	.0070	
N × P	.0310	2	.0155	.84
N × P × S	.6991	38	.0184	
T × P	.1414	2	.0707	2.68
T × P × S	1.0054	38	.0264	
F × N × T	.2613	1	.2613	6.68[b]
F × N × T × S	.7438	19	.0391	
F × T × P	.0912	2	.0456	4.30[b]
F × T × P × S	.4012	38	.0106	
F × N × P	.1203	2	.0602	2.83
F × N × P × S	.8088	38	.0213	
N × T × P	.1448	2	.0724	3.46[b]
N × T × P × S	.7934	38	.0209	
F × N × T × P	.0298	2	.0149	1.80
F × N × T × P × S	.3170	38	.0083	
Subjects	36.2282	19	1.9067	
Total	51.9930	479		

[a] $p \leq .01$
[b] $p \leq .05$

tractions (F × N) and familiarity with position of contractions (F × P) were statistically significant at the .01 level of confidence and familiarity with type of contraction (F × T) was significant at the .05 level of confidence. Among the second-order interactions the following were statistically significant at the .05 level of confidence: F × N × T, F × T × P and N × T × P. The third-order interaction failed to reach statistical significance.

A product-moment correlation coefficient was computed between IQ scores and average recognition thresholds for each subject. The numerical value of this coefficient was .57 which is significantly greater than zero at the .01 level of confidence.

Discussion

In Study II familiar words were found easier to recognize than unfamiliar words. In addition it was found that familiar contracted words were easier to recognize than familiar uncontracted words however this situation was reversed for unfamiliar words. The present study indicates that those effects are related to the number of contractions in a word. Increasing the number of contractions in a familiar word adds to its ease of recognition. However increasing the number of contractions in an unfamiliar word makes recognition even more difficult.

The effects that type of contractions has on ease of recognition are in part determined by the familiarity of words. For example, familiar words having lower contractions are recognized more easily than familiar words having contractions containing dots in all rows of the braille cell. The reverse is true for unfamiliar words.

Word familiarity also influences the effects of position of contractions within words. Familiar words with contractions in the middle of the word are recognized more easily than are familiar words with contractions at the beginning or end of the word. Words with contractions at the end are the most difficult among familiar words to recognize. Such is not the case for unfamiliar words, where difficulty of recognition diminishes as the position of the contraction moves from the beginning to the end of the word.

A complex relationship exists among word familiarity, number of contractions, and type of contractions. For words containing one contraction, familiar words containing contractions whose dots fall in all three rows of the braille cell are easier to recognize than those with low contractions. Just the reverse of this is true for unfamiliar words. For words containing two contractions, familiar words with low contractions are easier to recognize than similar words with contractions whose dots fall throughout the whole braille cell. For unfamiliar words with two contractions, just the reverse is true.

Equally complex relations exist among familiarity, type of contraction, and position of contraction. It appears that position is a significant variable for certain combinations of types of contractions and degrees of word familiarity. Familiar words with contractions whose dots fall throughout the braille cell are read most easily when the contraction is in the middle position. Familiar words with contractions in the initial or middle position are less difficult than those with such contractions in the final position. For unfamiliar words with contractions whose dots fall throughout the braille cell, difficulty of recognition increases as the contraction moves from the initial to the final position. For unfamiliar words with low contractions, difficulty decreases as the contraction shifts from the initial to the final position.

The number of contractions in a word influences the effects upon word legibility of type and position of contractions. For words containing one contraction, whether dots fall in the whole cell or in the lower part of the cell, these effects appear the same. The order of ease of reading (from easiest to most difficult) for these as well as words with two contractions with dots distributed throughout the cell is middle, initial and final. Such is not the case for words containing two contractions one of which is a low contraction. For these the order of ease of recognition is final, middle and initial.

In summary the results of the study indicate that contractions effect the ease of recognition for braille words in quite complex ways. The number of contractions the position of contractions and the type of contraction have different effects on reading ease depending on the degree of familiarity. It would appear useful to study the interactions of these factors under conditions of greater variation. Such things as word length, multiple position of contractions within words, word structure, and increased number of contractions and their interrelationships with word familiarity should be explored.

TEN

Study V: Effects of Context upon Recognition Thresholds for Braille Words That Vary in Length, Familiarity, and Orthography

THE effects upon recognition thresholds of variations in the length, familiarity, and orthography of braille words were explored in Study II. Because these words were exposed in isolation, the question was raised whether similar effects would result if the words were exposed within a context provided by the presence of other words in a sentence structure. In order to answer this question, Study II was replicated under such conditions.

Subjects

As before, 30 legally blind braille readers from grades 9 through 12 of the Indiana, Ohio, and Tennessee schools for the blind served as subjects. None of these had participated in Study II, although several had participated in one of the subsequent studies. And as previously, all students in these grades took one form of the Gates Basic Reading Test, Type A, and were ranked in order of reading speed scores. Subjects then were selected randomly from the upper and lower third of this distribution. However, no subject in either group was selected who had a comprehension score lower than 20, or less than 83 percent correct. This operation resulted in the identification of two reading groups—fast and slow. Subject data are given in Table 26.

TABLE 26 Descriptive Data for Subjects

		Reading Time (min)	*Comp. Scores*	*IQ*	*Age (yrs)*	*Grade*	*Sex* M	F
Fast read.	M	17.72	23.33	118.86	15.88	9.93	7	8
	SD	3.89	1.23	21.66	1.67	.88		
Slow read.	M	33.58	22.60	96.50	16.50	9.47	11	4
	SD	4.74	1.64	19.57	1.81	.74		

Method

DESIGN The design was identical with that of Study II.

MATERIALS The materials used were identical with those of Study II with the exception that the materials for the braille characters were omitted.

APPARATUS Apparatus identical to that of Study II was used.

PROCEDURE Recognition thresholds for the stimulus words were determined as described for Study II with one exception. Each stimulus word served as the terminal word in a sentence presented auditorily to subjects immediately preceding its exposure. These sentences provided context for the stimulus word. An example for the stimulus word "message" is the following: I was pleased to learn you had received the *message*.

Only four of the five randomized orders for stimuli were used in this study. In order to diminish the effects of learning on the experimental outcome, a separate set of contextual sentences was developed for each randomized set of stimulus words. This meant that any given stimulus word might appear in any one of four different contexts.

In writing the contextual material, two principal criteria were observed. First, an attempt was made to have all sentences the same length. In actuality these ranged from nine to eleven words. Second, an attempt was made to write contextual material which, although meaningful when used with a word, would not allow the word to be guessed directly from knowledge of its context alone. This proved a difficult task and the resulting contexts varied somewhat in their cue value for word recognition and in their degree of readability. The orders of stimulus words and their contextual materials are given in Appendix D.

The sequence of events for each stimulus presentation was as follows. The subject sat with his principal reading finger located over the braille space just preceding the space where the first character in the stimulus word would appear. The experimenter read the contextual sentence aloud. When that point in the sentence was reached where the stimulus word should appear, the tachistotactometer was activated and the word appeared in braille form for a controlled period of time. The task for the subject was to report what he read. The exposure times were systematically increased until each word was recognized.

The experimenters recorded the responses given upon each exposure of the stimulus words as before. In addition, the time of exposure at which at least one of the reading fingers of the subject traveled over all the characters included in the stimulus word was recorded. As before, this time was called the "cover time."

In order to compare the recognition times of words exposed in isolation with those of words exposed in context, it was necessary to analyze the results of Study II and the present study jointly. Therefore, these results were cast in a factorial design in which the analysis of the word variables, familiarity, length and orthography, was based on repeated measures of the same subjects with the design being replicated along the dimensions of reading speed and type of exposure (with or without context). These data were analyzed using analysis of variance techniques as described in Winer (1962)

Results

The results of the analyses of the data are reported in Table 27. This table shows that variation in the main effects—that is, length, familiarity, and orthography—results in significant differences in word recognition times. As indicated by the significant interactions, these factors are dynamically interwoven in their effects. Significant differences for word recognition times exist between the reading groups—fast and slow. The significant interactions among reading levels and the main effects indicate the differential influence of the latter upon the word recognition performances of the reading groups. These findings are identical with those discussed in Study II.

The major interest in this analysis, of course, lies with the effects of the type of exposure (isolated or in context) upon the recognition times for the stimulus words. The data analysis indicates that no significant simple over-all effect can be attributed to this source. Examination of some of the interactions between exposure type and the other variables in the experiment indicates, however, that under certain conditions context does affect the recognition times for words. Such significant interactions include familiarity with exposure type (F × E), length and familiarity with exposure type (L × F × E), length, familiarity, and exposure type with reading groups (L × F × E × R), and reading groups and orthography with exposure type (R × O × E).

TABLE 27 Analysis of Recognition Times for Isolated and Contextually Dependent Words

Source of Variation	*SS*	*DF*	*MS*	*F*
Between subjects	*127.945*	*59*		
E (exposure type)	.003	1	.003	
R (reading rate)	61.361	1	61.361	51.65[a]
E × R	.072	1	.072	
S. w. gr.	66.509	56	1.188	
Within Subjects	*104.526*	*660*		
L (length)	14.915	2	7.458	158.68[a]
L × E	.161	2	.080	
L × R	2.208	2	1.104	23.49[a]
L × E × R	.062	2	.031	
L × S. w. gr.	5.296	112	.047	
F (familiarity)	48.272	1	48.272	347.28[a]
F × E	3.164	1	3.164	22.76[a]
F × R	3.611	1	3.611	25.98[a]
F × E × R	.162	1	.162	
F × S. w. gr.	7.800	56	.139	
O (orthography)	.259	1	.259	11.77[a]
O × E	.033	1	.033	
O × R	.007	1	.007	
O × E × R	.103	1	.103	4.68[b]
O × S. w. gr.	1.206	56	.022	
L × F	1.515	2	.758	25.27[a]

Source of Variation	*SS*	*DF*	*MS*	*F*
L × F × E	1.031	2	.516	17.20[a]
L × F × R	.594	2	.297	9.90[a]
L × F × E × R	.435	2	.218	7.27[a]
L × F × S. w. gr.	3.362	112	.030	
F × O	2.284	1	2.284	65.26[a]
F × O × E	.227	1	.227	6.49[b]
F × O × R	.210	1	.210	6.00[b]
F × O × E × R	.033	1	.033	
F × O × S. w. gr.	1.976	56	.035	
L × O	.099	2	.050	
L × O × E	.063	2	.032	
L × O × R	.137	2	.068	
L × O × E × R	.071	2	.036	
L × O × S. w. gr.	2.541	112	.023	
L × F × O	.496	2	.248	13.05[a]
L × F × O × E	.049	2	.024	
L × F × O × R	.021	2	.010	
L × F × O × E × R	.036	2	.018	
L × F × O × S. w. gr.	2.087	112	.019	
Total	232.471	719		

[a] $p \leq .01$
[b] $p \leq .05$

A comparison of the mean recognition times for words exposed in isolation and in context according to the different conditions of the experiment can be made from Table 28. This comparison reveals that context under the conditions of the experiment, aids in the recognition of familiar words, but interferes with the recognition of unfamiliar words. The longer the word, the greater this effect. In addition, results of such interactions are much more severe for the slow reading group. The results of the effects of the interaction of familiarity and context are greater for contracted words than for uncontracted words.

Table 29 compares ratios of mean recognition times to mean cover times for words exposed in isolation and in context under the varying conditions of the experiment. Cover time was defined as that time of exposure during which at least one of the reading fingers of the subject passed over all characters in the stimulus word. If a subject recognized a word before this point, he was assigned a cover time of zero for that word.

While no formal statistical analysis was made of these data, several trends are apparent. Recognition times exceed cover times for three-character words under all conditions of exposure. As words increase in length, the size of the ratios decrease. For familiar words, as words get longer these ratios tend to become less than one and the effect of context is to accelerate this decrease. For longer unfamiliar words, these ratios, while reduced, remain well above one and the effect of context is to increase the size of the ratios over those obtained for words in isolation.

TABLE 28 Comparison of Mean Recognition Times for the Same Words in Isolation and in Context

Word Types	*Fast Readers*		*Slow Readers*	
	I	C	I	C
	3-character words			
FUnc	.53	.38	.82	.82
Fc	.54	.42	.86	.78
UnfUnc	.74	.76	1.19	1.28
UnfC	.78	.85	1.30	1.42
	5-character words			
FUnc	.63	.58	1.11	1.21
FC	.56	.47	1.00	.86
UnfUnc	.88	.92	1.53	1.73
UnfC	.99	1.12	1.77	1.85
	7-character words			
FUnc	.74	.60	1.31	1.02
FC	.70	.50	1.32	.84
UnfUnc	.94	1.02	1.71	1.92
UnfC	1.02	1.15	1.90	2.27

In Study II it was found that subjects recognized words before all characters were touched in 10 percent of the cases. For exposure in context, the proportion of words similarly recognized rose to 19 percent. A comparison of these results for the two studies is given in Table 30. Practically no such recognition occurred for three-character words.

Familiar words were recognized much more frequently than unfamiliar words, with contracted familiar words highest in order of recognition. Both these effects were enhanced when words were exposed in context.

TABLE 29 Comparison of Recognition Time to Cover Time Ratios for the Same Words in Isolation and in Context

Word Types	*Fast Readers*		*Slow Readers*	
	I	C	I	C
		3-character words		
FUnc	1.26	1.27	1.30	1.52
FC	1.26	1.45	1.26	1.47
UnfUnc	1.80	2.38	1.98	2.33
UnfC	1.77	2.74	1.78	2.58
		5-character words		
Func	1.14	1.18	1.22	1.48
FC	1.06	.94	1.05	1.12
UnfUnc	1.49	1.77	1.64	2.04
UnfC	1.60	2.11	1.70	2.23
		7-character words		
FUnc	1.09	.74	1.20	.90
FC	.94	.75	1.02	.86
UnfUnc	1.25	1.28	1.44	1.41
UnfC	1.26	1.44	1.41	1.54

Discussion

Contextual material preceding a word can significantly aid in the recognition of the word when displayed under the conditions of the experiment. However, this effect is quite specific. It does not occur in the case of short (three-character) words or in the case of unfamiliar words. Only with longer familiar words is this effect obtained.

As familiar words increase in length, context becomes more useful as an additional cue for word recognition. It appears more effective in decreasing the recognition times for familiar contracted words than it does for familiar uncontracted words.

The effects of context are exactly the reverse for unfamiliar words. As unfamiliar words increase in length, the presence of contextual ma-

TABLE 30 Comparison of the Number of Words Guessed Before All Characters Were Sensed When the Same Words Were Read in Isolation and Context

Word Types	*Fast Readers* I	*Fast Readers* C	*Slow Readers* I	*Slow Readers* C
	3-character words			
FUnc	1	2	2	0
FC	0	0	0	0
UnfUnc	0	0	0	0
UnfC	0	0	0	0
	5-character words			
FUnc	11	9	9	5
FC	15	22	10	15
UnfUnc	0	1	0	0
UnfC	0	1	0	1
	7-character words			
FUnc	12	31	13	27
FC	0	38	15	36
UnfUnc	1	9	1	5
UnfC	1	3	0	3
Total	61	116	50	92

terial appears to add to the difficulty of their recognition. This effect is greater for contracted than uncontracted unfamiliar words.

These effects apply differentially to the reading groups. The presence of context helps slow readers in word recognition only when words are long. The adverse effects of context in increasing recognition times for unfamiliar words appear greater for slow readers.

ELEVEN

Study VI: Effects of Context Occurring in Continuous Text on Recognition Times for Stimulus Words of Study II

IN STUDY II and subsequent studies it was found that the word characteristics—familiarity (F), length (L), and orthography (O)—produced significant variation in the recognition threshold times of the words studied. However, the recognition times were obtained for words presented in isolation on a rapid exposure device which made the reading situation abnormal. As a consequence, a question arose as to whether a more normal reading situation would alter the effects of these word variables. The study reported herein was concerned with this problem.

Subjects

The subjects were 13 fast and 13 slow readers in grades 9 through 12 at the Overbrook School for the Blind. As before, the subjects were selected on the basis of their reading times and comprehension scores on the Gates Basic Reading Test, Type A, Form 3. Among all of the braille readers in grades 9 through 12 approximately 40 scored 20 or above on comprehension. These 40 readers were divided at the median on their reading times into a fast and a slow group, and from each half 13 subjects composing the levels of reading rate (R) were randomly chosen. The reading rate for the fast readers was approximately 129 wpm and that for slow readers 65 wpm. The present subject selection differed from that of earlier studies (see Study II) in that previously, a larger group of readers from more than one school was available, and the fast and slow readers were selected from the upper and lower thirds of the distribution of reading times. Only one school was used for the present study because of scheduling restraints, and because no school differences in the results on the recognition task had been found in four previous studies. Other data were also obtained on the subjects. This information can be found in Table 31.

TABLE 31 Subject Data

		Reading Time (min)	*Compre-hension*	*IQ*[a]	*Age*[a]	*Grade*	*Sex* M	*Sex* F
Fast readers	M	16.34	23.38	117.62	16.28	10.00	10	3
	SD	1.98	.77	12.77	1.79	1.22		
Slow readers	M	32.30	23.15	102.54	17.86	10.69	6	7
	SD	12.25	1.21	12.21	1.82	1.32		

[a] Results of "*t*" test indicated fast and slow readers significantly differed on this factor, $p < .05$

Method

In order to achieve a more normal reading situation in which to investigate the effects of the word variables, a short story was written incorporating the experimental words of Study II. The story in braille form was read aloud by the subjects and their reading behavior was recorded on tape.

DESIGN The design was the same as that for Study II.

MATERIALS Due to the difficulty involved in developing a story around such unrelated and, in some cases, infrequently found words as those used in Study II, very few restrictions were placed upon the use or position of the words in the sentences. An effort was made to distribute the words evenly throughout the story. This effort met with only partial success. The story in its final form contained 1,248 words. (See Appendix E.)

The story was published in braille in booklet form by the American Printing House for the Blind in accordance with their standard printing procedures with one exception. This exception was that none of the experimental words were allowed to begin or end a line.

APPARATUS Oral readings of the short story were recorded on a Butoba tape recorder, model MT 5. The recording of the story was then expanded in time through use of a Tempo-Regulator, model MLR 38/15. The Tempo-Regulator is a device which can increase the time of a recording by periodically repeating and inserting minute bits of the sound signal. The effect of the process is to increase the original recording time without distortion of the sound. In the present case the original recording time was expanded by approximately 185 percent. This amount of expansion proved quite adequate for measuring the reading times of individual words with an ordinary stopwatch. A Galco #915 stopwatch was used for this purpose.

PROCEDURE Two sessions were required of each subject. The first was a group session in which the selection test (Gates Basic Reading) was given. There were three of these sessions, each involving no more than 20 students. The sessions were run consecutively, with each session being approximately one hour in duration.

The second session consisted of the subject, individually, reading aloud the short story while the experimenter recorded the reading on magnetic tape. The reading of the story took place in an ordinary classroom setting with only the experimenter and the subject present. The subject sat at a library-type table with the story booklet before him. Behind the booklet was the microphone and the recorder. To the right of the subject was the experimenter. The subject was instructed to read the story in ". . . your normal speaking voice. . . . " "Do not stop or make any comments until after the completion of the story." The subject was told to ". . . try to figure them [unfamiliar words] out and pronounce them as you would if you were reading for your own pleasure." The reading sessions averaged around 25 minutes for each subject. The schedules for the subjects' reading sessions were arranged by classes—all the subjects from a given class being sent one at a time to the reading room without regard for their reading efficiency.

The Recording Department of the American Printing House for the Blind expanded the original recordings. From the expanded version a disinterested observer measured the reading times of the experimental words. The reading time of a word was defined as the time from the completion of the last sound of the preceding word to the completion of the last sound of the experimental word. An ordinary stopwatch was used to obtain this measure. To determine the reliability of this procedure, the word reading times of two randomly selected subjects from each of the two reading levels were remeasured and a correlation coefficient computed between the two timings. The four coefficients ranged from .90 to 1.00, and showed that the method of measuring was quite reliable.

Results

The measures recorded in Table 31 show that the reading level groups differed on intelligence and age. The fast readers were approximately 15 points higher on IQ scores and were 1½ years younger in age than the slow readers. A *t* test showed these differences to be significant at less than the .05 level of confidence. Thus, the fast readers appeared to be more intelligent and somewhat younger than the slow readers.

TABLE 32 Means and Standard Deviations of Each Treatment for Fast and Slow Readers

		Familiar Words					
		Uncontracted			Contracted		
		3	5	7	3	5	7
Fast readers	M	.51	.94	1.08	.58	.95	1.23
	SD	.24	.66	.38	.18	.31	.61
Slow readers	M	.72	1.66	2.60	1.06	1.50	2.65
	SD	.50	1.02	2.61	.83	.94	1.54
		Unfamiliar Words					
		Uncontracted			Contracted		
		3	5	7	3	5	7
Fast readers	M	1.83	2.89	2.58	2.38	4.21	4.10
	SD	.97	1.51	1.02	1.06	1.88	2.06
Slow readers	M	5.35	8.52	6.18	7.18	11.06	14.35
	SD	3.66	8.07	4.10	8.47	6.07	10.60

The mean word recognition times and standard deviations for each experimental condition appear in Table 32. The word reading times were analyzed by analysis of variance techniques similar to those used in the previous studies. The results of this analysis are contained in Table 33.

All the main effects and the first-order interactions were significant.

TABLE 33 Analysis of Expanded Word Reading Times

Source	*SS*	*DF*	*MS*	*F*	*Factors Sig. in Study II*
Between subjects	*2,575.608*	*25*			
R (reading rates)	847.013	1	847.013	11.76[a]	S[a]
Subj. w. groups (S. w. gr)	1,728.595	24	72.025		
Within subjects	*5,709.704*	*286*			
F (familiarity)	1,647.767	1	1647.767	33 67[a]	S[a]
F × R	478.814	1	478.814	9.78[a]	S[a]
F × S. w. gr.	1,174.460	24	48.936		
O (orthography)	145.892	1	145.892	24.69[a]	S[a]
O × R	45.517	1	45.517	7.70[b]	S[b]
O × S. w. gr.	141.804	24	5.908		
L (length)	208.684	2	104.342	14.08[a]	S[a]
L × R	49.954	2	24.977	3.37[b]	S[a]
L × S. w. gr.	355.820	43	7.413		
F × O	129.787	1	129.787	22.04[a]	S[a]
F × O × R	45.243	1	45.243	7.68[b]	
F × O × S. w. gr.	141.349	24	5.890		
F × L	52.740	2	26.370	7.66[a]	S[a]
F × L × R	12.938	2	6.469	1.88	
F × L × S. w. gr.	165.264	48	3.443		
O × L	48.444	2	24.222	3.43[b]	
O × L × R	30.017	2	15.008	2.13	
O × L × S. w. gr.	338.885	48	7.060		
F × O × L	49.082	2	24.541	2.85	S[a]
F × O × L × R	33.356	2	16.678	1.93	
F × O × L × S. w. gr.	413.887	48	8.623		
Total	8,285.312	311			

[a] $p \leq .01$
[b] $p \leq .05$

These results, with one exception, duplicated those of Study II. The exception was the orthography by length interaction which was significant in the present study. A comparison of the outcomes of the two studies are presented at the right of Table 33.

Since the principal objective of the present study was to investigate changes in the effects of the word variables due to more natural reading conditions, only departures from the results of Study II will be described. The first of these was the orthography by length interaction noted above. This interaction appeared to result from disproportionate increases in the reading times of the contracted words over times for the uncontracted words as word length increased.

In other words, reading times for contracted words appeared to positively accelerate as they increased in length and reading times for the uncontracted words appeared to negatively accelerate as they increased in length. For the same words in Study II there was an almost constant negative acceleration of the recognition times of both the contracted and uncontracted words with increases in length.

The second effect deviating from that of Study II was the F × O × R interaction. This interaction was not significant in Study II but was significant in the present study. This interaction appeared to result from differential reactions to the unfamiliar, contracted words among fast and slow readers. The slow readers required considerably more time to read the unfamiliar words than the fast readers. Also, the slow readers required more time to read the contracted unfamiliar words when compared with the uncontracted than did the fast readers. In Study II, however, except for the familiar, contracted words being recognized in slightly less time than the familiar, uncontracted by both groups of readers, the direction of differences in reading times for the categories of unfamiliar words were the same as those of the present study, but the differences were not great enough to be significant.

The third and final difference between the two studies involved the F × O × L interaction. This interaction was significant in Study II but not in the present study. In Study II this interaction appeared to be the result of the longer, familiar, contracted words being recognized in less time than the same categories of uncontracted words, while the short, familiar, contracted words required more time than their uncontracted counterparts; among the unfamiliar words of all lengths the contracted words required more time to be recognized than the uncontracted. In the present study the contracted words, in almost all cases, required longer reading times than the uncontracted words.

Discussion

Results of the present study substantiate, for the most part, the findings of Study II. Hence the method used in Study II appeared valid for investigating the characteristics of words which affect their perception in the reading process.

Some differences between the two studies were found. The differences appeared to be a reflection of dissimilar methods for measuring the recognition times for the words. In Study II, the criterion measure was the exposure time necessary to recognize the word while in the present study it was word reading time which included the response or pronunciation time. This latter measure appeared to be influenced by the additional syllables in those words containing contractions. All of the interactions which were different between the two studies involved the contracted words and appeared to stem from the longer times necessary to say these words. For this reason, these findings of the present study differed from those of Study II.

These new findings may indicate another facet of braille reading which would require a modification of the conclusions drawn from the results of Study II.

In Study II, because the longer, familiar, contracted words were recognized in less time than the same kinds of uncontracted words, it was assumed that this was a general effect of contractions. However, this may only be true for the special situation in which the words were studied. It may not be true for the normal reading situation if pronunciation is a general feature of braille reading as it was for oral reading in the present study. Such a possibility is highly feasible considering the slow rate and synthetic nature of braille reading. Moreover, the possibility is supported by observations from the previous studies which showed that a large number of readers move their lips while reading silently and that many of them can even be heard reading the text softly word for word.

If pronunciation does affect the reading times of braille words then the role of contractions in words might vary depending on whether they represent part of a whole word sound or the whole or part of one of a number of sound units making up a word. More explicitly, the "and" contraction can be the whole or part of a separate sound or syllable as in the word "candy" and also part of the whole word sound as in "brand." Both of the examples would be considered contracted words but the two syllables of candy may, other things being equal, produce a longer reading time than for the word brand. Thus, the influence contractions have on the reading times of words may, at least in part, depend on the sound units they represent in words.

One other interesting finding of the present study was the difference in the IQs of the fast and slow readers. The average IQ for the fast readers was 117, and was approximately 15 score points higher than the IQ of the slow readers. This was the fourth study in which similar results were obtained. In none of the studies was IQ a condition for subject selection; the principal criterion was always reading rate. Thus, these findings corroborate one another and strongly suggest that IQ is a very important factor in the development of braille reading rates. No reliable information on this question has been found and a study of the perceptual behavior of low IQ readers may be fruitful.

TWELVE

Study VII: Effects of Familiarity, Length, and Orthography of Braille Words on Their Recognition Thresholds at the Elementary School Level

IN STUDY II and subsequent studies a number of characteristics of language, the braille code, and the reader were found to influence word and character recognition. These findings were of considerable import and contained many implications for the reading and teaching of braille. However, the subjects of these studies were skilled braille readers from grades 9 through 12, and the results could not be validly extended to readers in the lower grades. To determine whether the findings were applicable to less experienced readers and whether developmental factors affected word and character recognition, Study II was replicated with subjects from the elementary grades.

Subjects

The subjects were 15 fast and 15 slow braille readers from grades 4 through 6 of the Indiana, Kentucky, and Tennessee residential schools for the blind. These grades were chosen because they appeared to represent the earliest level at which the children would be able to work adequately with the same experimental materials as the older readers. There were a number of reasons for this expectation. One was the results of studies of braille reading by Fertsch (1932) which showed that the mechanical reading habits of the blind become established by around the third grade. Another was the conclusion based on teacher communication that, for most, the symbology of the braille code had been taught by around the fourth grade.

The subjects were chosen, as in the previous study, on the basis of their performance on the Gates Basic Reading Test. The limits of the upper and lower thirds of the distribution of reading speeds for these grades on this test were defined by results of earlier unpublished research involving several hundred children. These limits were used as criteria for selection of fast and slow groups of readers. An additional criterion was a comprehension score of 70 percent or more.

All children in grades 4 through 6 at each participating school were given the Gates Test Type A. At each school two groups of children meeting the criteria just described were identified and approximately five children were randomly selected from each group. The number selected at each school varied because two subjects selected initially were unable to complete the experimental tasks. In this case they were replaced by randomly selected alternates from one of the schools visited subsequently.

Selection of students in this manner led to identification of a group who read approximately 88 wpm and a group who read approximately 42 wpm. Descriptive data for the groups can be found in Table 34.

TABLE 34 Subject Data

		Read. Time (min)	*Comp. Score*	*IQ*	*Age (yrs)*	*Grade*	*Sex* M	F
Fast readers	M	23.60	21.67	93.36	11.95	5.07	7	8
	SD	6.25	2.19	13.30	1.28	.80		
Slow readers	M	51.03	22.13	99.58	12.82	5.00	11	4
	SD	9.12	1.30	15.10	1.57	.84		

Method

DESIGN The design replicated that of Study II permitting a direct comparison of its results with those of the present study. The comparison took the form of a multiple factor analysis of variance of the combined results of both studies.

Results

The subject data in Table 1 suggest that the groups of fast and slow readers may have differed on age and IQ. However, *t* tests of these differences indicate that they were not significant at the .05 level of confidence. This lack of differences between the fast and slow readers on IQ scores was quite surprising, since previous studies had consistently demonstrated differences on this factor. However, this finding is apparently an accurate reflection of the relationship between IQ and reading rate at these grade levels. Intelligence quotient scores were available for 79 of the 88 children given the Gates tests. These scores were correlated with reading rate and the resulting coefficient (—.09), is not significantly different from zero. On the other hand, a significant positive correlation of .35 was found between IQ and comprehension. Thus, it was found that at grades 4 through 6 IQ was correlated with comprehension, but not reading rate.

Table 35 presents the means and standard deviations of the recognition thresholds for each condition of the present study. Similar data for high school readers can be found in Study II (Table 11). Comparison of results of the two studies reveal the much longer recognition times required by elementary readers as well as the greater variability of behavior in this group.

An analysis of variance (Winer, Chap. 7) of the recognition times showed that, with only two exceptions, the same effects were significant for the elementary readers as were for the high school readers. This information is contained in the right-hand columns of Table 36. The two exceptions were the first-order interactions of familiarity or orthography with reading rates. These two interactions were significant for the high school readers but not for the grade school. Among the high school readers these interactions showed that the transition from frequent to infrequent and uncontracted to contracted resulted in considerably longer recognition times for the slow readers than for the fast. Such a differential effect failed to appear among the younger readers.

The results of a combined analysis of the word recognition times

TABLE 35 Means and Standard Deviations of Each Treatment for Fast and Slow Elementary Readers

		Familiar					
		Uncontracted			Contracted		
		3	5	7	3	5	7
Fast readers	M	.76	.95	1.14	.74	.87	1.08
	SD	.22	.28	.33	.20	.20	.30
Slow readers	M	1.20	1.46	1.92	1.06	1.36	1.71
	SD	.30	.45	.49	.35	.35	.48

		Unfamiliar					
		Uncontracted			Contracted		
		3	5	7	3	5	7
Fast readers	M	1.13	1.55	1.83	1.28	1.79	2.13
	SD	.26	.33	.47	.37	.40	.64
Slow readers	M	1.40	1.79	2.16	1.65	2.28	2.73
	SD	.53	.48	.61	.57	.57	.71

of the grade and high school readers take up the greater portion of Table 36. These reveal the consistency of the findings of the two studies plus identifying a number of other significant effects involving grade levels. Only the latter will be discussed.

The main effect of grade levels and five interactions involving grade levels were significant. The main effect difference resulted from the high school readers requiring less time than the elementary readers to recognize the words. Two of the significant interactions were familiarity by grade and length by grade. Both were the result of increases in complexity of each of the variables being characterized by disproportionately longer recognition times among the grade school readers than among the high school readers. Another significant interaction, familiarity by length by grade, was produced by a differential effect between grade levels of the shift from familiar to unfamiliar as the words became longer. For the high school readers this change involved a relatively constant increase in recognition times, but for the grade school readers the same change involved an accelerating increase in

TABLE 36 Combined Analysis of Word Recognition Times for Studies II and VII

Source	*SS*	*DF*	*MS*	*F*	*Sep. Analysis*	
					VII	II
Between subjects	*159.131*	*59*				
G (grade levels)	39.335	1	39.335	30.78[b]	*S*	*S*
R (reading rates)	47.797	1	47.797	37.40[b]		
G × R	.425	1	.425			
Subj. w. gr.	71.574	56	1.278			
Within subjects	*135.078*	*660*				
L (length)	36.807	2	18.404	283.14[b]	*S*	*S*
L × G	4.483	2	2.242	34.49[b]		
L × R	3.398	2	1.699	26.14[b]	*S*	*S*
L × G × R	.090	2	.045			
L × Subj. w. gr.	7.261	112	.065			
F (familiarity)	49.439	1	49.439	325.26[b]	*S*	*S*
F × G	3.469	1	3.469	22.82[b]		
F × R	.282	1	.282	1.86		*S*
F × G × R	.936	1	.936	6.16[a]		
F × Subj. w. gr.	8.545	56	.152			
O (orthography)	1.102	1	1.102	26.24[b]	*S*	*S*
O × G	.129	1	.129	3.07		
O × R	.097	1	.097	2.31		*S*
O × G × R	.007	1	.007			
O × Subj. w. gr.	2.336	56	.042			
L × F	1.565	2	.782	21.72[b]	*S*	*S*
L × F × G	.729	2	.364	10.11[b]		
L × F × R	.019	2	.010			
L × F × G × R	.121	2	.060	1.67		
L × F × Subj. w. gr.	3.989	112	.036			
F × O	2.905	1	2.905	90.78[b]	*S*	*S*
F × O × G	.447	1	.447	13.97[b]		
F × O × R	.143	1	.143	4.47[a]		
F × O × G × R	.013	1	.013			
F × O × Subj. w. gr.	1.783	56	.032			
L × O	.015	2	.008			
L × O × G	.046	2	.023	1.10		
L × O × R	.055	2	.028	1.33		
L × O × G × R	.119	2	.060	2.86		
L × O × Subj. w. gr.	2.350	112	.021			

					Sep. Analysis	
Source	*SS*	*DF*	*MS*	*F*	*VII*	*II*
L × F × O	.460	2	.230	14.38[b]	*S*	*S*
L × F × O × G	.033	2	.016	1.00		
L × F × O × R	.079	2	.040	2.50		
L × F × O × G × R	.001	2	.000			
L × F × O × Subj. w. gr.	1.825	112	.016			
Total	294.209	719				

[a] $p \leq .05$
[b] $p \leq .01$

recognition times. The fourth interaction, familiarity by orthography by grade, was apparently the result of the shift from uncontracted to contracted within the unfamiliar word category having a differential effect on the two groups of readers. Both groups recognized the familiar contracted words in slightly less time than the familiar, uncontracted. However, the same shift within the unfamiliar words was accompanied by disproportionately greater recognition times among the grade school readers than among the high school readers. The fifth significant interaction involving grade levels was familiarity by grade by reading rate. This interaction resulted from the fast and slow grade school readers requiring about the same additional time to shift from recognition of familiar to unfamiliar words; while to make the same shift, the fast high school readers required considerably less additional time than the slow high school readers.

Table 37 gives the mean recognition threshold times for the 32 single cell braille characters for the grade school readers. Also in Table 37 are the median, range, and correlation of the distributions. Similar data for the high school readers can be found in Study II (Table 13). The correlation between the recognition times for the grade school and high school readers was .78, $p < .01$.

An analysis of the character recognition times for the grade and high school readers showed all of the effects, except for the characters by rates interaction, to be significant. This information is presented in Table 38.

TABLE 37 Mean Recognition Times of 32 Braille Characters for the Elementary Readers

	Fast	*Slow*		*Fast*	*Slow*
A	.15	.15	U	.17	.17
B	.15	.19	V	.18	.19
C	.15	.17	W	.18	.19
D	.18	.18	Y	.19	.19
E	.16	.16	th	.16	.18
F	.18	.19	ar	.16	.16
G	.17	.18	ble	.18	.19
I	.16	.17	ow	.22	.22
J	.18	.18	st	.22	.18
K	.15	.18	in	.19	.18
L	.16	.18	ch	.20	.18
M	.15	.16	er	.24	.21
N	.17	.19	en	.20	.19
O	.16	.16	and	.20	.21
Q	.24	.25			
R	.21	.20			
S	.16	.16			
T	.17	.19			

Median: .17; .18
Range: .15–.24; .15–.5
r: .78; $p < .01$

The faster readers recognized the characters in less time than the slow readers; the high school readers required less time than the grade school readers, and the fast high school readers required considerably less time to recognize the characters than the slow high school readers. However, the fast and slow grade school readers showed no such marked differential, even though there was a slight over-all difference favoring the fast grade school readers.

The characters by grades and the characters by rates by grades interactions indicated that some of the character recognition thresholds differed among the reading rate and/or grade groups. In general, it appeared that the fast grade school readers differed more from the fast high school readers on the contractions while the slow grade and high school readers differed more on the alphabet characters. Also both

TABLE 38 Analysis of Recognition Times of Characters for Elementary and High School Readers

Source	*SS*	*DF*	*MS*	*F*
Between subjects	*6.8727*	*59*		
R (reading rates)	.8797	1	.8797	12.22[b]
G (grade levels)	1.2210	1	1.2210	16.96[b]
R × G	.7420	1	.7420	10.31[b]
Error	4.0300	56	.0720	
Within subjects	*3.5755*	*1860*		
C (characters)	.7653	31	.0247	16.47[b]
C × R	.0323	31	.0010	
C × G	.0702	31	.0023	1.53[a]
C × R × G	.0703	31	.0023	1.53[a]
Error	2.6374	1736	.0015	
Total	10.4482	1919		

[a] $p \leq .05$
[b] $p \leq .01$

groups of elementary readers appeared to have more difficulty than the high school readers with some of the contractions. A few of the contractions requiring longer recognition times by the grade school readers were st, ch, er. Many alignment and reversal errors were made on these characters. Results of analyses for other characteristics of the symbols which differed among the groups were fruitless.

Table 39 shows the mean word recognition times for each condition of the present study. Similar data for the high school readers can be found in Study II (Table 15).

In some of the categories it was found that the cover and/or word recognition times were shorter than the synthetic word times. This was due to those kinds of words being identified before all the characters were sensed. The frequency of occurrence of this phenomenon can be found in Table 40. Similar data for the high school readers is contained in the report on Study II (Table 17). The results for the elementary and high school readers were much the same. The high school readers correctly anticipated 111 words compared to 96 for the elementary groups. With only four exceptions all of the words were from the familiar category; almost twice as many were contracted as compared with uncontracted and all but three were five and seven characters in length.

TABLE 39 Mean Word Recognition Times, Cover Times, and Synthetic Recognition Times for Elementary Readers

	Mean Word Recognition Time (sec)		*Mean Cover Time (sec)*		*Synthetic Recognition Time (sec)*	
	Fast	Slow	Fast	Slow	Fast	Slow
		3-character words				
FUnc	.76	1.02	.60	.82	.48	.50
FC	.74	1.06	.61	.85	.48	.52
UnfUnc	1.13	1.40	.64	.87	.51	.52
UnfC	1.28	1.65	.62	.85	.57	.55
		5-character words				
FUnc	.95	1.46	.85	1.24	.84	.88
FC	.87	1.36	.82	1.30	.88	.88
UnfUnc	1.55	1.79	.80	1.27	.80	.85
UnfC	1.79	2.28	.85	1.30	.90	.91
		7-character words				
FUnc	1.14	1.92	1.10	1.68	1.14	1.18
FC	1.08	1.71	1.00	1.78	1.21	1.24
UnfUnc	1.83	2.46	1.13	1.87	1.12	1.16
UnfC	2.13	2.73	1.17	1.91	1.21	1.25

TABLE 40 Number of Words Correctly Anticipated Before All the Characters Were Touched

	Fast Readers				*Slow Readers*				
	Familiar		Unfamiliar		Familiar		Unfamiliar		
	Unc	Con	Unc	Con	Unc	Con	Unc	Con	
3	—	—	—	—	—	—	—	—	0
5	6	9	—	—	8	12	—	—	35
7	11	17	—	—	9	23	—	1	61
Total	17	26	—	—	17	35	—	1	96

Discussion

The findings of the present investigation show both similarities and differences among the effects of the variables studied on the word recognition behavior of elementary and high school readers. Like effects appear to indicate a similarity in the dynamics of the word recognition process for the two grade levels. Unlike effects seem to reflect factors arising from the developmental process in learning to read.

Three effects of importance were similar for the two grade levels. The first involved the influence of changes in complexity of the variables word length, familiarity, and orthography upon word recognition. For both the elementary and high school readers increase in the complexity of these variables resulted in significant increases in the times required for word recognition. Differences existed between the groups here which will be discussed later. A second similarity involved the differences among the synthetic word times, the cover times, and the word recognition times. For both groups of readers the synthetic times were the shortest, the cover times intermediate, and the word recognition times the longest. The third similarity was the phenomenon of correctly anticipating a word before all of its characters had been sensed. Both groups engaged in this behavior to almost the same degree.

These findings point to a communality in the dynamics of the reading processes that characterize both groups. These dynamics appear to be the following. Information was acquired from each character in the word as they were sensed sequentially. This information was integrated during movement across the characters and further synthesized after all of the characters were sensed. Characteristics of the language and of the braille code influenced this process. Peripheral cues arising from these sources helped the readers to reduce the amount of time required to integrate the information contained in the characters and consequently to recognize a word. At times the information stemming from peripheral cues was sufficient to enable the readers to guess the identity of the word before having sensed all of the characters contained. The part of the word that was guessed was the ending, but that only after the characters in the fore part were sensed sequentially.

Five differences between the groups of grade school and high school readers were considered important. Two of them involved the interactions of the factors word length or orthography with the factors familiarity and grade levels. These appeared to stem from the fact that cues arising from certain combinations of word length and familiarity or combinations of familiarity and orthography were used to recognize words to a much greater extent by high school readers than by elementary readers. This finding probably reflected the greater experience with the relative probabilities of the occurrence of letter combinations in words as expressed in the braille code.

The third difference involved the interaction of characters with grade levels. Some of the contractions were considerably easier for the high school readers to recognize than for the grade school readers. Why this was the case is not clear. It may reflect lower levels of reading experiences of elementary readers coupled with the relative infrequency of occurrence of certain forms of contractions. In a sample of 291,000 words from 12 books, Kederis *et al.* found that the alphabet characters appeared three times as often as the single-cell contractions. Thus, these differences probably reflect differing amounts of experience or practice in reading.

The other two differences were those between the fast and slow readers within the two grade levels. These differences appear to have a developmental source also. They involved the relationships between the reader's intelligence and average character recognition time. At the high school level the average IQ of the fast readers was 20 points higher than that of the slow readers. At this same level the average character recognition time for the fast readers was approximately one half that for the slow readers. Consequently, it was concluded that intelligence and its resulting limitations on character recognition were determinants of reading rate. In the present study of elementary readers, no such intellectual differences between groups of fast and slow readers were found. Parenthetically, there was a small difference in character recognition favoring the fast readers, but it appeared too small to have any significant effect on reading rate. It is necessary, therefore, to explore the reasons for these differences among high school and elementary school readers.

Inspection of Table 34 reveals that the mean IQ of slow readers appears greater than that of fast readers. While differences between these are not statistically significant, their comparison points to a zero order or even negative correlation between IQ and reading speed. That this order of relationship between these variables is indeed the case for braille readers at these grade levels is confirmed by results obtained by the authors. For the group of 79 elementary children from which subjects in this study were chosen, correlation between IQ and reading time was calculated to be −.09.

These findings for braille readers differ considerably from those for print readers. Smith and Dechant in describing numerous studies of print readers state: " . . . the correlation between these two sets of scores has been found to range from about .35 to .80" (p. 89). In addition, they cite studies reporting correlations between IQ and reading achievement which indicate a low relationship in grade 1 (.35) which increases in size up through grade 6 (.65). From these data they suggest that ". . . mental age actually is a more basic determinate of reading success when children have reached the stage at which they read to learn than it is when they are learning to read."

Smith and Dechant go on to identify a number of basic factors more highly related to early reading achievement than IQ. Among these are found auditory and visual discrimination, language development and breadth of the individual's experience. It is highly likely that factors of these kinds are more critical in early braille reading development than IQ. Lowenfeld (1963, p. 243) describes the educational retardation of blind children and points out the restrictions in experience consequent to blindness. Hayes (1938) and others have documented the severe retardation often found in vocabulary development within this group. Nolan and Morris (1960) have studied the development of tactual discrimination among young blind children and found it related to years of school experience. Consequently, low levels of development in these very basic areas probably tend to negate effects of variability in IQ on braille reading development.

However, assuming the validity of these findings and also the findings of studies III, V, and VI where positive relations were found between IQ and reading times for high school subjects, there must be a period in the development of reading where IQ begins to differentiate the fast and slow braille readers. Data on reading rates and grade levels suggest this period may be immediately beyond the grade levels sampled in the present study. Figure 2 shows a graph of reading rates by grade levels for 321 braille readers. The graph indicates something approaching a plateau between the fifth and sixth grades followed by a sharp increase in reading rate in the seventh grade. These changes in the curve quite possibly occur as a consequence of the development in the basic factors approaching their maximum thereby freeing the reader to begin to use peripheral cues stemming from language redundancy as aids in word recognition. His ability to do this apparently has a high positive relation to his intelligence. The shift in mode of reading from straight character integration to character integration augmented by peripheral cues is probably responsible for the reduced rate of growth in reading speeds shown between grades 5 and 6.

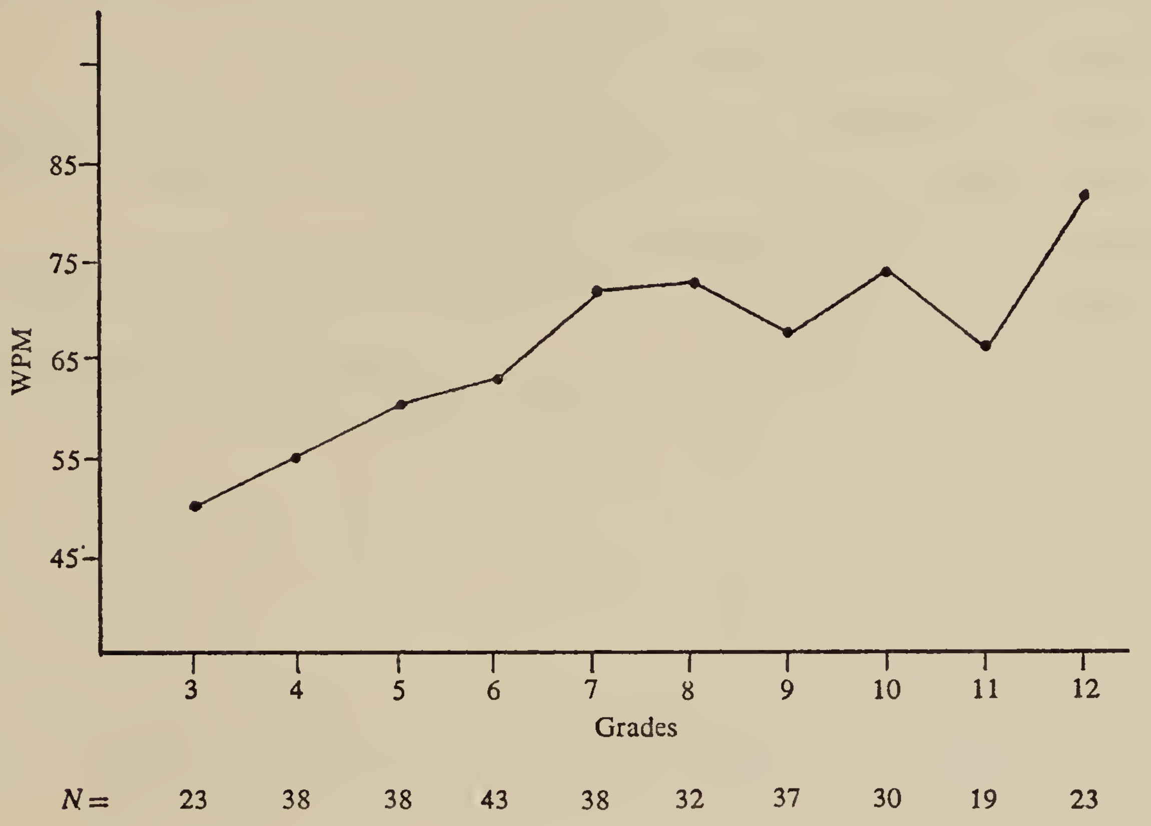


FIGURE 2. *Average WPM Braille Reading Rates by Grades on the Gates Basic Reading Test, Type A, Form 1 at Four Residential Schools for the Blind*

A similar explanation can account for the fact that the fast and slow elementary reading group do not differ in speed of character recognition. Development of tactual ability in both sensory and motor modes must occur to a certain degree before blind children can discriminate the braille forms. Opportunity for such development is independent of intelligence in preschool years. Once in school, opportunities among blind children for development in this area become approximately equal. When this development has leveled off and children have learned to discriminate braille forms, they are then free to apply peripheral sources of information to their recognition. One such source is experience with the relative occurrence of braille characters in print. As described in Study I, Kederis *et al.* (1965) report a correlation of .46 between relative frequency of occurrence and the ease with which braille characters are recognized. Peripheral cues aiding in character recognition within words would result from experience with frequency of occurrence with combinations of letters within words and knowledge of word form. Ability to utilize peripheral cues in character recognition would appear to be directly related to intelligence.

In conclusion, the findings of the present study, while indicating a similarity in the essential nature of reading between the two grade levels, also showed some grade specific differences in reading, particularly with regard to the role of IQ and character recognition. These differences appear not only of a developmental kind, but also point toward the existence of other factors important to success in early reading achievement, especially rate of reading. Thus, the present study provided some answers, but at the same time, and perhaps more importantly, showed the great need for further study in this area.

THIRTEEN

Study VIII: Braille Word Recognition by Readers of Low Intelligence

FOUR previous studies of braille reading (ss II, III, V, and IV) revealed that among secondary school braille readers high intelligence was associated with rapid reading rates. In each of the studies the groups of subjects selected on the basis of fast reading speeds averaged around 120 on IQ scores, while the groups selected for slow reading speed averaged around 100. However, among elementary school readers selected in the same fashion no IQ differences were found between fast and slow readers (Study VII). Both elementary groups averaged around 95 on IQ scores. Consequently, it appears that in the early stages of reading development intelligence is only minimally related to reading rate. However, in later stages of development of the reading process (somewhere near the upper elementary grades) it becomes a signficant factor influencing reading speed.

These findings suggested that readers with IQs ranging below 85 may develop only very slow reading rates and that the reading rates of low IQ readers may not show significant increase from one educational level to the next. This condition, if true, would have considerable educational significance. The present study was concerned with these questions, and also with whether the effects of the factors studied previously would be the same for the reading behavior of the low IQ readers. Information relevant to these questions was obtained by replicating Study II using as subjects low IQ readers at the elementary and secondary school levels.

Subjects

The subjects were 15 elementary and 15 secondary school children from three residential schools for the blind. An effort was made to obtain the subjects from the same grade levels as were used in Study II and Study VII—that is, 9 through 12 and 4 through 6. This, however, was not completely possible because many of the children were in ungraded classes and only 7.5 percent of the group from which the secondary subjects were drawn were in grades 11 and 12. Hence, the secondary children came principally from grades 7 through 9. In the case of the special or ungraded classes the teachers and principals were asked to roughly specify the grade levels at which the children were working.

The subjects were selected on the basis of their IQ scores which were obtained by the schools during their normal course of student evaluation. Some of the scores came from the Interim Hayes-Binet; however most were based on the Verbal Scale from the Wechsler Intelligence Scale for Children. The criteria for subject selection was an IQ score of 85 or under. This figure was chosen because it is one SD below the sighted mean for the Wechsler test and in the vicinity of one SD below the mean for blind children on the Hayes-Binet (Wechsler, 1949; Hayes, 1943; Gilbert and Rubin, 1965; Hopkins and McGuire, 1966).

Another factor entering into subject selection was the comprehension score obtained from the Gates Basic Reading Test, Type A, Form 3. All of the students at the test schools, working at the grade levels specified, who had IQ scores of 85 and under were given this test. Those readers who scored 9 and under in comprehension were dropped from the pool of subject candidates. This score was only 3 points above the chance level and, consequently, it was thought the experimental task would be too difficult for readers scoring at this level. The number of students exempted in this way amounted to 12 at the elementary level and six at the secondary. Exempting these students had the effect of inflating the average reading times and comprehension scores of the remaining subjects because a number of the exempted students were apparently not reading at all and finished the test in less than average time. The mean reading rates for the pools of elementary and secondary subjects were 39 and 40 wpm, respectively.

Data describing the subjects are given in Table 41, and reading data for the entire group of students who were given the Gates test are given in Table 42.

At each of the test schools five or six subjects were randomly selected at each of the two school levels from the number of low IQ readers not exempted by the comprehension condition. Five or six subjects was the number that an experimenter could work with in a one week period. The total number of students from which the 30 subjects were selected was 96. Two of the subjects chosen initially were unable to perform the task and had to be dropped from the study. They were replaced by randomly selected alternates.

TABLE 41 Subject Data

		Reading Time (min)	*Comp. Score*	*IQ*	*Age (mos)*	*Grade*	*Sex* M	*Sex* F
Grade school	M	53.76	18.07	76.60	149.60	4.20	8	7
	SD	13.69	4.11	6.32	9.88	.86		
High school	M	51.97	18.73	75.49	196.73	8.00	6	9
	SD	16.59	5.15	8.81	19.66	1.00		

Method

The design, materials and apparatus of the study replicated those of Study II.

PROCEDURE The procedure was similar to that of Study II, except that the Gates reading test was administered approximately a week, instead of a month, prior to data collection, and data collection required, in the case of some subjects, six sessions instead of five.

Results

The reading times and comprehension scores for all of the low IQ children given the Gates test are presented in Table 42.

TABLE 42 Reading Data for Entire Group of Children with IQs of 85 and Under from Which Subjects Were Chosen

		Reading Time (min)			*Comprehension*		
	N	Range	M	SD	Range	M	SD
Elementary	52	15 89	42.15 (50 wpm)	16.57	0 24	16.12	7.32
Secondary	44	20 89	41.41 (51 wpm)	18.53	4 24	18.27	5.94

The reading times and comprehension scores for the total group were slightly lower than those of the subject sample. This was due, as was mentioned before, to exemption of subjects with low comprehension.

An extremely interesting and important finding was the absence of a difference in reading rate between the elementary and secondary readers. Both groups read, on the average, at approximately 50 wpm. It was also found that only eight of the elementary readers scored 50 percent or better on comprehension and read more than 75 wpm. Only one of these eight read above 100 wpm, at 140 wpm. For the secondary readers the parallel figures were 9 and 1. Thus, in reading rate these two groups were very much alike.

From incomplete data it was estimated that the low IQ elementary readers given the Gates test represented 30 percent of the total enrollment in the grades at which they were working, or said to be working. For the secondary readers this figure was 20 percent. These percentages should not be considered as highly reliable because of the ungraded classification of many of the students. However, they do show that these low IQ children represented a significant proportion of the enrollment at the schools studied.

In Table 43 the means and standard deviations of the word recognition times for all experimental conditions can be found. The average times for the individual conditions showed considerable consistency between the elementary and secondary readers. However, the secondary readers exhibited greater variation within the conditions than the elementary readers, which was evidenced by the SD's. Over-all, the sec-

TABLE 43 Means and Standard Deviations of Each Condition for Low IQ Readers

		Familiar					
		Uncontracted			Contracted		
		3	5	7	3	5	7
Elem. read.	M	1.20	1.69	2.26	1.25	1.85	2.14
	SD	.29	.51	.81	.38	.62	.68
Sec read.	M	1.36	1.80	2.31	1.38	1.92	2.44
	SD	.59	.80	1.14	.59	1.02	1.48

		Unfamiliar					
		Uncontracted			Contracted		
		3	5	7	3	5	7
Elem. read.	M	1.48	2.08	2.68	1.90	2.54	3.02
	SD	.50	.45	.77	.64	.80	.89
Sec. read.	M	1.67	2.40	2.76	2.11	2.91	3.22
	SD	.65	.90	1.05	.83	1.21	1.37

ondary readers required 9 percent more time to recognize the words than did the elementary readers.

A comparison was made of the total average word recognition times for the elementary and secondary readers of studies II and VII and the elementary and secondary readers of the present study. It revealed that the low IQ elementary readers required 33 percent more time to recognize the words than the elementary readers of Study VII and the low IQ secondary readers required 111 percent more time than the secondary readers of Study II. Thus, at the elementary level, differences in intelligence appeared associated with sizable differences in average word recognition time which at the secondary level became greatly accentuated.

In Table 44 are the results of an analysis of variance of the word recognition times from the present study. Only four of the effects were significant. Three were the main effects of the word characteristics; the other was the interaction familiarity by orthography. The significance of the main effects resulted from the familiar, uncontracted, shorter words being recognized in less time than the other levels of these conditions. The familiarity by orthography interaction appeared to result from the unfamiliar, contracted words requiring considerably longer recognition times than the familiar contracted which, in turn, required more time than the familiar uncontracted.

In studies II and VII this same interaction was also significant, but for different reasons. In those studies the unfamiliar contracted words likewise required longer recognition times than the unfamiliar uncontracted, but the familiar contracted words required less time than the

TABLE 44 Analysis of Word Recognition Times of Low IQ Readers

Source	*SS*	DF	*MS*	*F*
Between subjects	*193.4328*	*29*		
G (grades)	2.9160	1	2.9160	
Subj. w. groups (S. w. gr.)	190.5168	28	6.8041	
Within subjects	*159.5565*	*330*		
F (familiarity)	32.3520	1	32.3520	136.85[a]
F × G	.1832	1	.1832	
F × S. w. gr.	6.6214	28	.2364	
O (orthography)	5.6050	1	5.6050	29.67[a]
O × G	.0786	1	.0786	
O × S. w. gr.	5.2910	28	.1889	
L (length)	67.8389	2	33.9194	90.16[a]
L × G	.0604	2	.0302	
L × S. w. gr.	21.0715	56	.3762	
F × O	3.2263	1	3.2263	42.06[a]
F × O × G	.0001	1	.0001	
F × O × S. w. gr.	2.1488	28	.0767	
F × L	.4893	2	.2446	2.64
F × L × G	.3285	2	.1642	1.77
F × L × S. w. gr.	5.1918	56	.0927	
O × L	.2006	2	.1003	1.12
O × L × G	.1695	2	.0847	
O × L × S. w. gr.	5.0279	56	.0897	
F × O × L	.0104	2	.0052	
F × O × L × G	.0547	2	.0273	
F × O × L × S. w. gr.	3.6066	56	.0644	
Total	352.9893	359		

[a] $p \leq .01$

familiar uncontracted. Thus, it appeared that the low IQ readers, as opposed to those of average and above IQs did not benefit at all from inclusion of contractions in familiar words.

There were also other differences between the low IQ readers and those of studies II and VII which appeared in the analysis of variance. In both Study II and VII several of the other interactions were significant. These seemed to reflect the utilization as cues in recognition of some of the more complex relationships among characteristics of the words. Such behavior did not characterize the low IQ readers.

TABLE 45 Mean Recognition Times of 32 Braille Characters for Low IQ Readers

Character	*Elem.*	*H. S.*	*Character*	*Elem.*	*H. S.*
A	.15	.24	S	.15	.23
B	.16	.24	T	.18	.24
C	.15	.21	U	.19	.23
D	.17	.22	V	.19	.24
E	.16	.25	W	.18	.24
F	.17	.23	Y	.19	.25
G	.17	.23	th	.19	.25
I	.17	.24	ar	.16	.22
J	.17	.25	ble	.20	.25
K	.17	.24	ow	.23	.27
L	.15	.24	st	.22	.25
M	.16	.23	in	.21	.27
N	.19	.25	ch	.18	.24
O	.16	.23	er	.21	.26
Q	.23	.33	en	.23	.31
R	.18	.26	and	.18	.29

Median for all characters: .17; .24
Range: .15–.23; .21–.33
Correlation between elem. and H. S. readers: $r = .73$; sign. $p \leq .01$ level of confidence

In Table 45 the average recognition times of the 32 single cell braille characters can be found. Also shown in the table are the median, range, and rank-order correlation for the two groups of readers. These figures indicate that the elementary readers required less time to recognize the characters than did the secondary readers. However, in an analysis of variance of the recognition times the two grade levels did not differ significantly. The only effect in the analysis that was significant was that of the characters, for which $p < .01$.

A comparison was made between the character recognition times of the low IQ readers and the readers of studies II and VII. It showed that the low IQ elementary readers recognized the characters in about the same amount of time as the other elementary readers, but that the low IQ secondary readers required approximately 89 percent more time to recognize the characters than the secondary readers of Study II. Thus, at the elementary level there was not much difference in character recognition times among readers who varied in intelligence, but at the secondary level the readers of average and above average intelligence were considerably more efficient at character recognition than the low IQ readers.

Average recognition times, the average cover times, and the average synthetic recognition times for each condition of the present study are

TABLE 46 Means of Recognition, Cover, and Synthetic Recognition Times of the Experimental Words

	Recognition Time		*Cover Time*		*Synthetic Recog. Time*	
Word Type	Elem.	H. S.	Elem.	H. S.	Elem.	H. S.
			3-character words			
FUnc	1.20	1.36	1.08	1.11	.49	.72
FC	1.25	1.38	1.09	1.17	.52	.72
UnfUnc	1.48	1.67	1.09	1.16	.51	.72
UnfC	1.90	2.11	1.09	1.16	.56	.74
			5-character words			
FUnc	1.69	1.80	1.55	1.71	.86	1.18
FC	1.85	1.92	1.53	1.86	.88	1.23
UnfUnc	2.08	2.40	1.54	1.70	.82	1.18
UnfC	2.54	2.91	1.69	1.86	.90	1.26
			7-character words			
FUnc	2.26	2.31	2.06	2.27	1.16	1.68
FC	2.14	2.44	2.18	2.63	1.20	1.73
UnfUnc	2.68	2.76	2.12	2.43	1.13	1.67
UnfC	3.02	3.22	2.23	2.57	1.23	1.74

given in Table 46. The synthetic times were the shortest, the cover times intermediate, and the word recognition times the longest. Similar findings were obtained for the readers of studies II and VII. Thus, it appeared that the basic approach of the three groups in reading the words was similar—that is, the words were read on a character-by-character basis.

A comparison was made of the over-all averages of these times among the three groups of readers. It showed that the secondary readers of Study II had the shortest times, the elementary readers of Study VII were intermediate, and the low IQ elementary and secondary readers, in that order, had the longest times.

Another comparison was made of the average time lag between the synthetic recognition times and word recognition times for the three groups of readers. This comparison showed that in addition to the time required to recognize the characters in the word considerably more time was needed by the low IQ readers to recognize the words. The average time differences in seconds for the groups were: secondary Study II—.42; elementary, Study VII—.64; secondary, low IQ—.98; elementary, low IQ—1.15. Thus, after the lapse of a sufficient amount of time to recognize the components of the words, the low IQ readers required approximately twice as much additional time as the other groups of readers to integrate this information into a word recognition.

Coefficients for the rank order correlations of the character recognition times, the word recognition times and the Gates test reading times for the three groups of readers are presented in Table 47. The co-

TABLE 47 Intercorrelations of Character Recognition Times, Word Recognition Times, and Reading Times for High School Readers, Elementary Readers, and Low IQ Readers

	Character Recog. & Word Recognition	*Character Recog. & Reading Time*	*Word Recognition & Reading Time*
Secondary	.76	.70	.83
Elementary	.33	.20	.67
Low IQ	.08	−.16	.52

Coefficient required to be different from zero at the .05 level = .36

efficients showed that for the low IQ readers and the elementary readers character recognition times were not significantly related to either word recognition or reading time. For these same two groups word recognition was significantly correlated with reading time and to a greater degree among the elementary readers. For the secondary readers character recognition, word recognition, and reading time were all highly correlated. From these findings it appeared that in reading the ability to utilize cues stemming from the language and code characteristics depended on both the reader's intelligence and experience.

One other finding in the present study was considered important: the number of words correctly guessed before all of the component characters were felt. Approximately 9 percent of the words were so identified. Almost all were familiar words and most were contracted. The secondary readers made approximately 38 percent more such identifications than the elementary readers. This information can be found in Table 48.

TABLE 48 Frequency of Words Correctly Anticipated Before All the Characters Were Sensed

	Elementary Readers				*Secondary Readers*			
	Familiar		Unfamiliar		Familiar		Unfamiliar	
	Unc	Con	Unc	Con	Unc	Con	Unc	Con
3	—	—	—	—	—	—	—	—
5	5	5	—	—	4	15	—	—
7	8	19	1	1	12	19	2	2
Total	13	24	1	1	16	34	2	2

Similar phenomena were found among the elementary and secondary readers of Study II and Study VII. However, they were more frequent among these readers than among the low IQ readers of the present study. Elementary readers of Study VII correctly anticipated 23 percent more words than the low IQ elementary readers, and secondary readers of Study II anticipated 3 percent more words than low IQ secondary readers. Thus, all of the readers studied so far employed to some degree this practice of anticipating words before sensing all of the component characters. The degree to which it was employed appeared to depend in part on the reader's intelligence and experience.

Discussion

In terms of the manner in which the subjects read the braille words, the present study indicated that the behavior of readers of low intelligence was basically similar to that of readers of average and above intelligence. In other words, all readers studied so far have exhibited the same basic process of identifying the words through integrating the component characters. Evidence for this conclusion came from the comparisons among the word recognition times, cover times, and synthetic word times. In all of the studies the synthetic times were the shortest, the cover times intermediate, and the word recognition times the longest. These differences showed that the readers required a certain amount of time to recognize and move from one character to another, and that the aggregate of these times for a word was considerably less than the recognition time for the word. Thus, these findings suggest most a character-by-character process of word recognition.

Another aspect of the word reading process that was similar among the groups was correct recognition of some of the words before sensing all the component characters. Each group of readers thus far studied identified from 7 to 10 percent of the words in this manner. This phenomenon appears to be a characteristic part of the braille reading process. It has been suggested that this feature of braille reading was solely a consequence of the method of obtaining the word recognition thresholds, that of minimal changes. However, the phenomenon has been noted in at least one other study using a different, more natural, methodology. Ashcroft, in a study of braille reading errors among elementary children, concluded: "There is a marked tendency to arrive at premature closure, and endings are missed, guessed at, or erroneously added" (1960, p. 68).

There were some other similarities in the reading behavior of low intelligence readers and those of average and above intelligence. For the most part, they involved ability to use charcteristics of the language and braille code as peripheral cues in word recognition. However, the groups also differed in these abilities. Because one effect cannot be discussed without the other being implied, only the difference among the groups will be treated.

The differences between the low IQ readers and those of average and above intelligence appeared primarily the result of slower central processing of information, a condition synonymous with low intelligence. These differences appeared in a number of the findings. The low IQ readers required more time than the other readers to recognize the words and characters and more time to move across or cover all of the characters. While generally true, this statement will be qualified below. Another time measure that identified the low IQ readers as slower involved the difference between the synthetic word times and the word recognition times.

Low IQ readers also differed from the other readers in that they were less able to utilize the characteristics of the language and the braille code to recognize the words. They were apparently responding only to the gross characteristics of the words as evidenced by the main effects of the experiment being significant. However, the interactions among these main effects were not significant, although they were for the readers of average and above intelligence. These findings imply that low IQ readers do not understand the relationships among word characteristics which serve as clues to the probabilities with which certain letters, letter combinations, syllables, and other words will follow.

It was stated above that low IQ readers had longer recognition times for the characters and words than the other readers. However, low IQ secondary readers exceeded elementary readers in times necessary for character and word recognition. The difference for character recognition was quite large while that for word recognition was slight. Consequently, the two elementary groups were very similar in character recognition and only slightly different in word recognition. But the two groups of secondary readers differed considerably on both character and word recognition. These results substantiated the conclusion, based on the results of studies II and VII, that at the elementary level variability in intelligence has not yet begun to produce variability in character recognition and word recognition.

This conclusion appears related to the finding that low IQ secondary readers were poorer than the elementary readers at character and word recognition. Both groups were similar in intelligence. The fact that secondary readers were poorer in character and word recognition but still had equivalent reading rates is probably attributable to the effects of practice and experience. During the conduct of the study some secondary readers stated they no longer read braille or else read it only when absolutely necessary. Thus, these readers may have had longer character and word recognition times resulting from disuse of the medium, but the effect of these times on reading rates would have been minimal due to the readers' greater knowledge and experience. Evidence for this appears in Table 8; secondary readers correctly anticipated almost twice as many words as elementary readers.

Probably one of the most important findings of the present study was that low IQ secondary readers did not read any faster than low IQ elementary children even though they were separated in age and grade by an average of four years. Furthermore, of the 96 low IQ readers given the Gates reading test only 15 read between 75 and 100 wpm and made a comprehension score of 50 percent or better. Only two read at a rate over 100 wpm. Thus, these children who for the most part would not be classified as ineducable, but who would be in the dull normal range of intelligence, were very slow readers, averaging 50 wpm. Significantly, there was no improvement in reading rate with advance in age and grade. These findings suggest that retarded intellectual development imposes a more severe limitation on learning to read braille than it does on learning to read print. Stated in other words, braille reading appears to be a more intellectually demanding task than print reading. This was suggested more than thirty years ago by Grasemann (1932).

Whether these children could be trained to improve their reading rates is problematical. Research with children to date (Kederis *et al,* 1967, and Flanigan, 1964) is not encouraging. As a group, these children represent a very important educational problem. They appear to have sufficient mental ability to learn, but not sufficient mental ability to make braille reading an efficient medium for this purpose. If their reading rates cannot be improved, it may be worthwhile to explore the effects of greater emphasis of the auditory channel for transmitting information to these children.

FOURTEEN

Study IX: Effect of Character Recognition Training on Braille Reading

THE findings of Studies II through VIII of the effects of stimulus characteristics on recognition times of words and characters suggest that braille word recognition is a process of character synthesis over a time-space sequence. Under these conditions the perceptual unit is the individual braille character. Operating on the assumption that the braille character is the perceptual unit, it was the purpose of the present investigation to determine what effect training for speed in character recognition might have on the efficiency of the reading process.

Subjects

Two groups of 12 subjects each were selected from grades 3 through 6 at the Kentucky School for the Blind. The limited number of stu-

TABLE 49 Factors Equating Experimental and Control Groups

	Sex			*Age*		*Motivated Pretest*	
Group	M	F	*Grade*	*(mos)*	*IQ*	Time	Comp
Exp.	4	8	4.75	148.08	98.50	27.94	20.42
Con.	4	8	4.75	146.42	96.83	27.64	20.42

dents in these grades precluded randomization or pair-matching. Alternatively, the groups were composed so that they were equated on sex, mean grade, age, IQ, and motivated reading achievement. Subject data are shown in Table 49.

Reading achievement consisted of reading time and comprehension scores for silent reading obtained on the Gates Basic Reading Tests, Type A. Initially, Form 3 of this test was administered in a group setting to all of the pupils in the above-mentioned grades. One week later Form 2 was administered to the same group in the same surroundings under motivated conditions. The motivating conditions were awards of three, two, and one dollars to the three pupils showing the greatest improvement in rate of reading with no decrease in comprehension scores. The motivated test was used to equate the experimental and control groups and was employed for the purpose of obtaining initial measures approximating optimum ability.

Method

CRITERIA FOR EVALUATING TRAINING EFFECTS To assess the effects of training in character recognition, three kinds of tests were used. A different form of each was used before and after training. One of the tests was a measure of rate and comprehension of silent reading. This was the Gates Basic Reading Test. Form 2 was given before training and Form 4 was given after training. Both forms were given under the same conditions and in the same surroundings.

The second test was a measure of rate and errors in oral reading. This test consisted of two passages, each approximately 400 words in length, dealing with the same topic and taken from a short story in a graded reading series. The passages were unfamiliar to all of the subjects.

The third test was a measure of rate and errors in the oral reading of the individual braille characters. It consisted of two forms of four different randomized orders of the 55 single cell braille characters that stand for letters or letter combinations. The 220 characters of each form were arranged in double-spaced rows, 11 characters each, on three sheets of paper. So the subjects would achieve correct spatial orientation, each of the characters was preceded and adjacent to the character composed of dots 4, 5, and 6.

Excepting the Gates tests, the latter two tests, both pre- and post-, and the training program were administered to the subjects individually in the same two rooms by two experimenters. During test administration each of the experimenters worked with one half of the experimental and control subjects chosen in a haphazard manner. During training the experimental subjects were daily alternated between the two experimenters.

TRAINING Each of the 12 experimental subjects was given practice in recognizing the 55 braille characters that stand for letters or letter combinations for periods of one half hour each day on 18 consecutive school days. The sole purpose of the training was to increase the rate and accuracy of identification of the characters.

TRAINING MATERIALS There were three types of practice materials. One was 20 separate lists of different random orders of the 55 braille characters. Each order was on a separate sheet of paper and was arranged in five double-spaced lines of 11 characters each. Each character was preceded and adjacent to the dots 4-5-6 character.

A second type of training materials was parallel forms of three kinds of character discrimination exercises. Each of the exercises used the 55 braille characters mentioned above. One of the exercises consisted of naming the different character within a set of three characters. Another involved naming a stimulus character and finding it within a set of three characters. The third type of discrimination exercise consisted of naming and counting the like characters within a set of four characters.

The third type of training materials was a set of 3-by-5-in. cards, each containing one of the 55, single-cell characters preceded by dots 4, 5, 6 in the adjacent cell.

On the day following administration of the character recognition pretest training began. At the outset the subjects were drilled, using the character cards, on those characters they had misidentified on the character pretest. The subjects were given the cards one at a time to examine carefully while the experimenter explained the character's meaning, its dot numbers, position in cell, and the features that distinguish it from the erroneous identification. Throughout training whenever any errors were made on any of the practice materials the character drill cards were used in the manner described before proceeding with new materials.

On each day of training the subjects read through a certain number of the lists, starting at three and gradually increasing to six as they reduced their reading times for the lists. On every second to third day one of the discrimination exercises was substituted for one of the lists of characters.

Daily records of reading times and errors were kept for each of the subjects. The reading times of the last two lists used each day were averaged and the subjects informed of their reading rates. The subjects were similarly informed of their reading rates for each of the discrimination exercises. The purpose of making the subjects aware of their reading rates was to motivate them to work against their own records.

Results

The three criterion tests yielded data on rate and comprehension of silent reading, rate and accuracy of oral reading, and rate and accuracy of character recognition.

The differences between the pre- and posttraining braille character recognition tests showed that the experimental group reduced their reading time of the characters by 42 percent, and their error rate by 83 percent. On the same tests, the control group reduced their reading time 15 percent and their error rate by 19 percent. The means and standard deviations of these measures are shown in Table 50.

An analysis of variance of the pre- and posttest character reading times showed that the training variable and the groups by training

TABLE 50 Reading Times and Errors in Braille Character Recognition

		Pretest		*Posttest*	
		Time (min)	Errors	Time (min)	Errors
Experimental	M	6.56	30.67	3.82	5.08
	SD	2.58	24.35	1.44	6.67
Control	M	5.51	15.18	4.66	12.36
	SD	1.85	10.24	1.21	11.46

interaction were significant beyond the .01 level of confidence. The latter effect resulted from the experimental subjects having proportionately greater increases in their character reading rates than the controls. The results of the analysis are shown in Table 51. No analysis was made of the error rates on the character tests because of the magnitude of the differences between the groups.

TABLE 51 Analysis of Variance of Reading Times for Braille Character Recognition

Source	*SS*	*DF*	*MS*	*F*
Between subjects	*125.61*	*22*		
Between groups	.13	1	.13	
Error	125.48	21	5.98	
Within subjects	*69.13*	*23*		
Training	38.95	1	38.95	41.00[a]
Interaction; group × train.	10.29	1	10.29	10.83[a]
Error	19.89	21	.95	
Total	194.74	45		

[a] p is $\leq$ .01.

The results of the Gates Basic Reading Tests were not so clear-cut as those of the character tests. Neither the experimental nor control group significantly reduced its mean reading time and comprehensive scores on the posttraining test. However, inspection of the individual scores for these tests suggests a slightly different interpretation of the outcome. Data for this appear in Table 52. Because of the hospitalization of one of their members, there are only 11 subjects in the control group.

Subjects E5, C6 and C9 did not meet the standard of maintaining their comprehension scores on the motivated posttests, and thus, apparently did not truly read the test material. Excluding these subjects for that reason, it was found that among the control subjects only two out of nine, or 22 percent reduced their reading time, and four out of nine, or 44 percent, increased their comprehension scores on the motivated posttest. On the other hand, among the experimental subjects,

TABLE 52 Motivated Pretest and Posttest Scores in Time and Comprehension of Silent Reading for Control and Experimental Groups

	Time			*Comprehension*		
Sub	Pretest	Posttest	Change	Pretest	Posttest	Change
			Control Group			
C1	41.17	36.88	—	24	24	0
C2	23.67	19.88	—	18	18	0
C3	45.25	46.83	+	23	23	0
C4	26.08	29.42	+	18	19	+
C5	21.70	21.80	+	23	23	0
C6	24.17	17.93	—[a]	14	4	—[a]
C7	14.47	15.35	+	21	24	+
C8	37.42	41.65	+	21	21	0
C9	35.00	16.92	—[a]	16	7	—[a]
C10	15.67	16.77	+	20	21	+
C11	16.93	20.53	+	23	24	+
Mean	27.41	26.70	—	20.09	18.91	—
			Experimental Group			
E1	25.27	36.97	+	15	23	+
E2	16.73	15.38	—	18	22	+
E3	34.43	38.23	+	24	22	—
E4	11.43	11.10	—	23	24	+
E5	41.87	39.50	—[a]	18	13	—[a]
E6	28.25	33.27	+	24	24	0
E7	31.58	24.38	—	24	24	0
E8	29.05	25.00	—	17	15	—
E9	32.92	26.20	—	22	23	+
E10	39.87	39.03	—	21	22	+
E11	30.50	30.37	—	20	20	0
E12	13.35	18.37	+	19	22	+
Mean	27.94	28.15	+	20.42	21.17	+

[a] Increase in rate could not be considered because of detrimental effect on comprehension.

seven of 11, or 64 percent, increased their reading rates and comprehension scores on this posttest.

On the oral reading posttest, the experimental subjects made significantly greater gains in reading efficiency over their pretest performance than did the control subjects. Mean reading rates and errors on this test are shown in Table 53

TABLE 53 Reading Rates in Words per Minute and Errors per 100 Characters for Oral Reading Tests

		Pretest		*Posttest*	
		Rates	Errors	Rates	Errors
Experimental	M	73.03	1.76	83.80	1.37
	SD	28.38	1.04	34.52	1.04
Control	M	76.73	2.10	76.06	2.01
	SD	31.44	2.14	30.05	1.86

The experimental subjects increased their oral reading rates by 15 percent and decreased their error rate by 28 percent. In comparison the control subjects performance changed hardly at all. An analysis of variance of the pre- and posttest reading rates of the experimental and control subjects showed that the training and interaction factors were significant beyond the .01 level of confidence. As before, the significant interaction meant there were reliable differences in the reading behavior of the experimental and control subjects following training. These differences, obvious in Table 53, favored the experimental subjects. The results of the analysis of variance are shown in Table 54

TABLE 54 Analysis of Variance of Oral Reading Rates

Source	*SS*	*DF*	*MS*	*F*
Between subjects	*40,318*.78	*22*		
Between groups	46.93	1	46.93	
Error	40,271.85	21	1,917.71	
Within subjects	1,311.40	23		
Training	323.36	1	323.36	11.08[a]
Interaction; group × train.	375.01	1	375.01	12.85[a]
Error	613.03	21	29.19	
Total	41,630.18	45		

[a] p is less than .01.

Discussion

Under the conditions of the present study the results indicated that training was effective in improving braille character recognition and that the improvement was accompanied by an increase in the efficiency of the total reading process. Hence, the results, considered within the narrow limits of the sample of the study, lend support to the conclusion that the perceptual unit in braille reading is the individual braille character.

The minimal and statistically nonsignificant difference between the experimental and control subjects on the Gates test following training was probably not an accurate expression of the effects of improved character recognition on reading. Instead, the results were most likely due to factors basically not a part of the reading process. The most important of these factors was undoubtedly the motivating conditions under which the tests were given. The monetary rewards were obviously overstimulating to a number of subjects. So much so, that some of the subjects skimmed the tests so rapidly they did not comprehend what they covered. This development could very easily obscure the effects of a short term training program on a small number of subjects.

A further illustration of the importance and magnitude of the effects of motivation in the reading activity was the difference in results of the first two trials on the Gates test. From unmotivated Form 3 to the motivated pretest, Form 2, the subjects decreased their reading times by approximately 20 percent. In calculating the percentage of reduction, the reading times of those subjects whose comprehension fell off were excluded. This finding was in accordance with similar results obtained by Kederis *et al.* (1967). On the same Gates test and using the same motivating conditions they obtained an average reduction in test reading time of 24 percent.

APPENDIX A

*Words Utilized As Stimuli in Studies II, V, VI, VII, and VIII**

	Uncontracted		*Contracted*	
Characters	Familiar	Unfamiliar	Familiar	Unfamiliar
Three	age	lug	both	garble
	law	irk	earth	joust
	use	soy	table	winch
Five	build	askew	certain	chimera
	front	facet	general	larceny
	voice	idiom	school	quandary
Seven	capital	habitat	breakfast	clandestine
	natural	deplete	government	nebulous
	message	salvage	remember	sedimentary

* The underlined portions of words represent contractions expressed as one or two braille contractions.

APPENDIX B

Stimulus Words Used in Study III

	Number of Dots in Word				
Contracted Words	11	13	15	17	19
Most dots in upper half	science	defeat	method	pledge	govern
	awhile	shield	pierce	sphere	hunger
Dots evenly distributed	incline	bureau	distinct	occupy	fortune
	combination	sentence	consult	injury	mutter
Uncontracted Words					
Most dots in upper half	canal	spade	ridge	negro	glory
	aside	decay	draft	droop	funny
Dots evenly distributed	mamma	pause	rural	trunk	worry
	abuse	skill	solve	rumor	sorry

Extra Words:	3 cell		7 cell	
	age	both	capital	breakfast
	law	earth	natural	government
	use	table	message	remember
	set	below	gradual	remarkable

APPENDIX C

Stimulus Words Used in Study IV

	One Contraction			*Two Contractions*		
	Initial	Middle	Final	Initial	Middle	Final
Whole cell FAMILIAR Lower cell	strait	author	modest	chariot	orchard	cluster
	shield	costly	exceed	startle	boundary	restless
	insect	refine	retain	distinct	destiny	succeed
	dispose	rabbit	burden	constant	general	seventh
Whole cell UNFAMILIAR Lower cell	chrome	cleric	codling	archive	bowshot	unearth
	shrive	hostel	pliable	charnel	costard	poacher
	innate	suffix	sequin	inertia	minaret	crabbed
	commode	append	cloven	forensic	libbard	amenity

Extra Words:	3 cell		7 cell	
	cry	lug	acquire	habitat
	wet	irk	picture	salvage
	man	winch	vegetable	deplete
	shoe	joust	companion	sedimentary

APPENDIX D

Study V: Contexts and Stimulus Words

1

1) There is little sparkle to a stone having only one *facet.*
2) It's very important, but many people don't take time for *breakfast.*
3) The deposits' size and form were amazing to have been *sedimentary.*
4) It is obvious that a habit is strengthened by *use.*

1) The window dresser left the clothes on the mannikin *askew.*
2) It was not incomprehensible, but it was certainly a strange *idiom.*
3) The slight young man had difficulty developing a good *build.*
4) It is impossible to forget your boyhood activities at *school.*

1) The merger of the companies would be advantageous to *both.*
2) From her appearance it was not easy to determine her *age.*
3) The distortion of facts in the essay resulted in *garble.*
4) The fermentation process brings out the flavor in the *soy.*

1) She possessed that quality of charm which is so *nebulous.*
2) The last event listed on the program was a *joust.*
3) It is not difficult to understand the necessity for *law.*
4) The man found the job brought on the condition of *irk.*

1) Many merchants find there is a good market for *salvage.*
2) He was a person of genius in his wildest *chimera.*
3) Although he was confident, the outcome was anything but *certain.*
4) One of man's greatest assets is his capacity to *remember.*

1) He enjoyed great popularity because his style was so *natural.*
2) Removing the furniture from the building was hard without a *winch.*
3) Although certain landmarks were familiar, it was not his customary *habitat.*
4) Everyone agreed the star was in his best *voice.*

1) We worked long and hard to make the speech less *general.*
2) The unusual design made a quite, odd looking *table.*
3) Although it made little difference, the conferences were usually *clandestine.*
4) The countryside was filled with the fragrant odor of *earth.*

1) I was pleased to learn you had received the *message.*
2) Many of the government offices were moved to the *capital.*
3) The additional information made the situation even more of a *quandary.*
4) The pack was so heavy it required a strenous *lug.*

1) The new insurance policy covers most types of *larceny.*
2) Because we were overstocked our only choice was to *deplete.*
3) For the fourth day it was quite on the *front.*
4) Nowadays, many people are strongly dissatisfied with the *government.*

2

1) In his deft manner he quickly corrected what was *askew.*
2) The conditions were such, their resources were impossible to *deplete.*
3) It's easy to detect the presence of brine in the *soy.*
4) His size caused people to refer to him as a *lug.*

1) The old man's most pleasant memories were those of *school.*
2) A beautiful example of symmetry and form was the sloop's *build.*
3) He endured great hardship and deprivation to deliver the *message.*
4) We missed our bus because it took so long for *breakfast.*

1) After the game a reporter described Jim's ability as *natural.*
2) It was the kind of thing you knew for *certain.*
3) The cards the man received left him in a *quandary.*
4) The early philosophers thought a basic constituent of matter was *earth.*

1) The University of Cologne has an outstanding Academy of *law.*
2) If the environment were more stimulating it might relieve his *irk.*
3) With such an indignity you would wrong his *age.*
4) From the import firm George purchased a large amount of *garble.*

1) The 22nd is the ignominious day we must all *remember.*

2) The incident was referred to as the disgrace of the *capital.*
3) Little attention was given his suggestion, which was merely a *chimera.*
4) The news was out even though they had been extremely *clandestine.*

1) The modification of the machine could not have benefited its *use.*
2) What he was thinking could not be discerned from his *front.*
3) It was more interesting than any other native *habitat.*
4) We were amazed to discover the depth of the boy's *voice.*

1) After much consideration he resigned his job with the *government.*
2) They knew the event would cause happiness for them *both.*
3) The unusually bad weather helped the skipper make a large *salvage.*
4) He developed it long enough, but the argument was still *nebulous.*

1) The audience and critics were delighted with the new play's *idiom.*
2) Contrary to the speaker's opinion, the issue has another *facet.*
3) A skillful, artful form of combat was the medieval *joust.*
4) Before he sold the truck the owner removed the *winch.*

3

1) All ships are equipped with many varieties of the *winch.*
2) We are about to witness the beginning of a new *age.*
3) She was astounded by the grotesqueness of the little boy's *chimera.*
4) Each branch of the service has its own platoon *school.*

1) Even after six weeks, the disposition of the case remained *nebulous.*
2) Compared with some other countries America does not use much *soy.*
3) The horse failed to make the jump and injured his *front.*
4) Time could not diminish the love of which he was *certain.*

1) At night the dog carried her pups under the old *table.*
2) Angered, the man told the tax collector he would not *deplete.*
3) It was such a personal experience, surely you can *remember.*
4) The anthropologist gave an interesting report on the American *natural.*

1) It should be considered if it represents the people's *voice.*
2) The construction workers first filled the hole with *earth.*
3) I had to admit I was not familiar with that *facet.*
4) He was pleased to learn he had been promoted to *general.*

1) Their choice of candidates placed us in a *quandary.*
2) Many groups do not share our feelings for a people's *government.*
3) The evidence clearly indicated a case of compound *larceny.*
4) The sail could not be secured, it was *askew.*

1) The role of the housewife has many moments of *irk.*
2) In some places on certain occasions they still hold the *joust.*
3) The aliens were under suspicion because they were too *clandestine.*
4) Having worked far into the night, we asked for *breakfast.*

1) The depth of the water made the ship difficult to *salvage.*
2) That they were mischievous was frequently said of *both.*
3) It is folly to disregard the influence of one's *habitat.*
4) The window frame was kept from falling out by the *lug.*

1) To find it we had to sift through considerable *garble.*
2) The new fighter planes require of the pilot a specific *build.*
3) The geologist was hoping the formations were something other than *sedimentary.*
4) A distinguished feature of our society is its system of *law.*

1) With that item it's hard to distinguish between purpose and *use.*
2) It was obvious that great delight was conveyed by the *message.*
3) Such business ventures require a considerable amount of *capital.*
4) Try as we could, it was impossible to understand their *idiom.*

4

1) That group of people belong within the class of the *natural.*
2) The solution was obvious after studying the thing's *front.*
3) I thought the funniest act was the clowns having a *joust.*
4) About many things it is difficult to be *certain.*

1) Because he achieved the extraordinary, the men respected their *general.*
2) It seems more consideration should be given to the object's *use.*
3) The speech disclosed his comprehension of the situation as quite *nebulous.*
4) The strange animal returned to its lair in the *earth.*

1) Even so, I'll have to admit his idea was *capital.*
2) A frequent comment by Sociologists concerns the stress of our *age.*
3) The professor asked the class, "How can the object be *sedimentary?"*
4) A difficult situation confronting young people involves their choice of *school.*

1) He was impeccably dressed, but his tie was *askew.*
2) Insurance companies recover a certain percentage of their losses from *salvage.*
3) Comfort and encouragement can often be imparted by a simple *message.*
4) As a filler dog foods contain a high proportion of *soy.*

1) The writer's talent was the rare use of an imaginative *idiom.*
2) The operation would have been successful except for the broken *lug.*
3) The situation was such that it only compounded her *irk.*
4) The criminal organization was sustained by an elaborate form of *government.*

1) Many difficult mechanical problems have been overcome with the *winch.*
2) He was normally shy, but anger gave him *voice.*
3) From the old door the carpenter built a beautiful *table.*
4) What causes a person to go to such lengths as *larceny?*

1) He was careful, but an irregularity appeared on the second *facet.*
2) The terms of the contract were acceptable to *both.*
3) Although not in the design, practical considerations influenced the *build.*
4) After our two financial failures we tried to *deplete.*

1) We could not convince him of unreality of his *chimera.*
2) Do you know anyone who enjoys being in a *quandary?*
3) Their mode of dress leaves little doubt of their *habitat.*
4) Such situations as those are usually covered by the *law.*

1) The unusual transactions required a meeting place that was *clandestine.*
2) The report will give the recommended nutritional content for *breakfast.*
3) The error resulted from the report that contained only *garble.*
4) The distraught young man repeated over and over, "I can't *remember.*"

APPENDIX E

Study VI: Short Story Read by Subjects with Stimulus Words in Italics

John could *remember* when he came to work for the department. He had not long been out of *school.* He felt then that he would be able to do something about corruption in the *government.* Now he wondered why he hadn't accepted one of the more attractive offers he had received upon graduation. Oh, he knew why; this job, he thought then, was one in which he could make a positive contribution to the good of his country and at the same time make a name for himself.

But things were different now. He was in a *quandary.* It wasn't the first, but this one wasn't the same as the others. Previously, most of his problems involved pressure from prominent men in the *capital* city, pressure that prevented him from carrying out his job of prosecuting those who broke the *law.* He had been aware of what he would be up against before accepting this position. His department was even jokingly referred to as the *sedimentary* station. Problems that were insoluble or that others were afraid to handle would settle down to his department and just stay there. The principals in many of the cases he had worked on were members of the legislature. One case concerned an attempt to *deplete* porkbarrel funds, in another it was a case of *larceny.* About half the cases involved *clandestine* activities that were, at least, unethical. And they all had one thing in common—the defendents, had the cases ever come to that, were all guilty. But he had not been allowed to prosecute. Pressure from various sources had forced him to drop the cases. Now, he had been assigned the case of prosecuting a member of the war department for treason. The man was a *general* who had been photographed passing a coded *message* to a foreign spy. The spy had been picked up and the message found written on the general's own stationery. Pretty damning evidence, but in this case John felt, was even *certain,* that the man was innocent.

It was a *nebulous* affair. He had been on the case for a whole month and had not learned much more than when he had started, except that more than ever he felt the general was innocent. He had established that the general's meeting with the spy had been part of his work. The general sometimes worked as a *front* man for the war department and personally delivered to the enemy ambassador material officials did not want publicized. The spy had been the enemy ambassador and had been under investigation for some time by the intelligence agency. The spy's arrest at this particular time and the seizure of the material given to him by the general was one of those unfortunate coincidences, as the war department was unaware of the intelligence agency's suspicions and activities. Naturally, the war department's documents were returned to them, but the coded message was a mystery to *both* departments and was the basis for the treason charge.

Oh! What's the *use,* he thought. He had covered every *facet* of the case, and nothing seemed to shed any light on the message. He had even gone to where the general was being held and talked with him. His conversation with the general had proved to be of no help, and the visit had served only to confirm his belief in the general's honesty. On his way out, he looked about and was halfway appalled by the conditions of the detention center. Such a place was a suitable *habitat* only for some of the animals he saw around. At the gate the same big *lug* who admitted him with a grunt was there to grunt him out.

On his way back to town in his car he sat numbed with disbelief. How could things like this happen, he questioned. It just wasn't *natural* for a man of the general's character to be involved in an affair like this. No power on *earth* could make him believe the general was collaborating with the enemy. And what tended to *irk* him even more was the fact that the war department would not come to the general's aid, and it was they who were responsible for holding the general in the detention center. John wondered if the general would be able to *salvage* any respect for his fellow men after this. To add to his annoyance, while engrossed in his thoughts an oncoming car had forced him off the highway and made him lose three hours getting a truck with a *winch* to pull him back onto the road.

John removed his feet from the *table* beside his desk. Well, tomorrow, he hoped, would see the end of this distracting experience. Tomorrow the preliminary hearing was being held.

That night John didn't sleep very well, and in the morning he was roused from a semi-conscious state by the sounds of a strange *idiom.* The sounds came from his daughter who was only two years of *age,* and who was pretending to be a prosecuting attorney. He delayed getting up as long as he could. He didn't feel like *breakfast.* Nor was he much concerned about his appearance; his wife let him know his tie was *askew* as he went out the door.

In the courtroom while arranging the material he needed for the trial, John thought, for him, this wasn't going to be the usual verbal *joust.* He had made it a point to *build* his case on just the facts, and these he would present as objectively and simply as possible. Then he looked around. He noticed some members of the cabinet and the general's immediate family. He wondered why the younger children had been brought to this sad spectacle. No doubt it was out of love and trust for their father and belief in the power of justice.

The trial began and John called his witnesses and presented his case as he had planned. The general's defense tried to develop their case around the contention that the message had been a plant by the enemy to bring about the general's downfall. John had suspected this might occur, and he had hoped it wouldn't. It was too obvious. Such a *chimera* implied that the enemy had some notion that their man would be caught. Besides that, they had nothing to gain from the general's dishonor. He had to point out the shortcomings of their argument.

The proceedings were not at all favorable for the general. As a matter of fact his cause seemed almost hopeless when he was called to take the witness stand. After a number of questions, the general was asked to read the message aloud. Apparently, the interrogator thought that confronted with his traitorous handiwork the defendent might make some admission of guilt. The general began reading the code very slowly. What he was reading sounded like so much *garble.* Just as he had finished the word *soy,* a small *voice* that came from the general's young son was heard to say, "Daddy, where did you get my secret code?"

How appropriate, John thought as a relief enveloped him, how appropriate that a little child should have the answer.

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